EXCLUSIVE gatefold pull-out star chart

EASY sky sights YOU can see TONIGHT p. 64

September 2005
Astronomy.com

Astronomy®

Observing, telescopes, origin and fate of the cosmos

What happens when galaxies COLLIDE?

Worlds are rocked, stars explode, infant suns turn on

Debris tails and a frenzy of star formation testify to the tidal forces generated when two galaxies pass near each other. This galaxy pair, nicknamed "the Mice," eventually will merge into one giant galaxy. PAGE 32

How the universe has surprised us p. 38

Why comets are not as pristine as astronomers thought

Stalking star clusters

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Vol. 33 • Issue 9

Purchase any RCX400™, LX200™GPS or LX90™ and save over $330 on genuine Meade accessories!†

See page 9 for details

† Valid until September 30th, 2005

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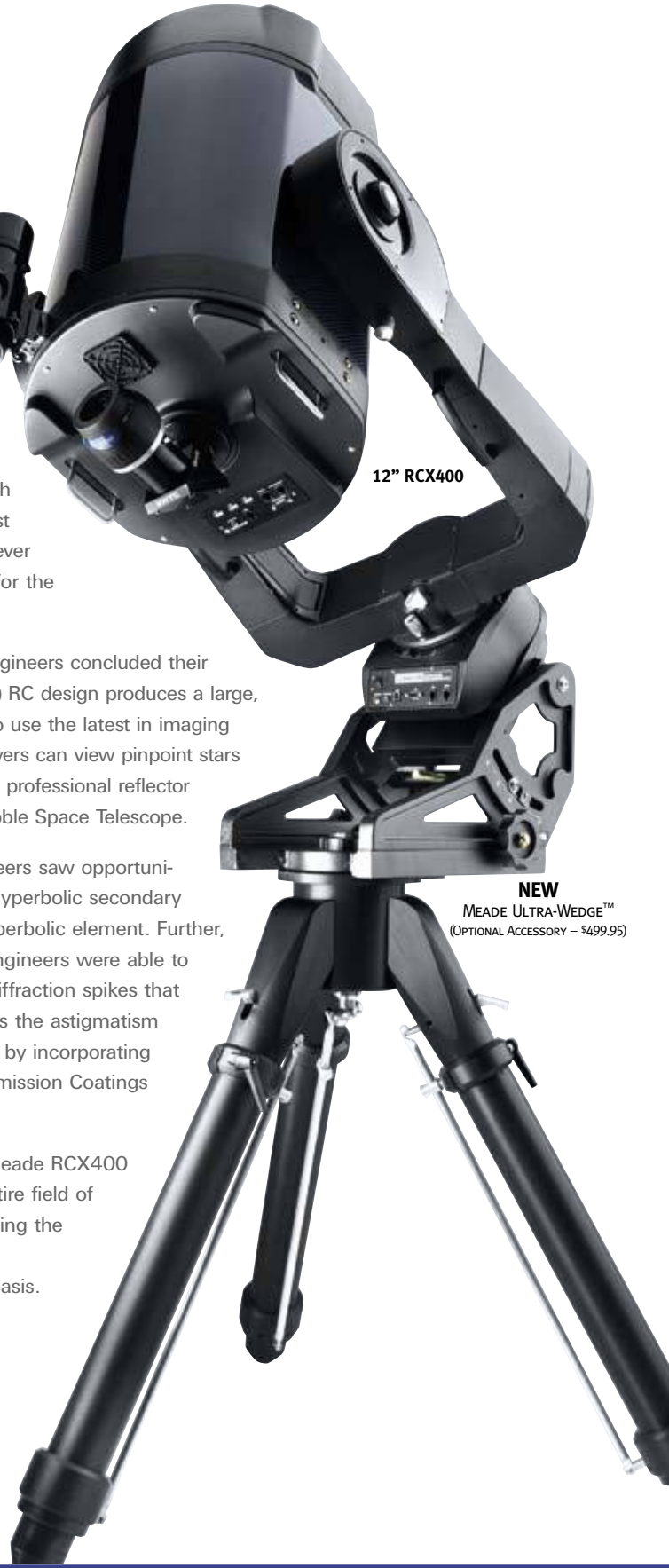
RCX400™

ADVANCED RITCHEY-CHRÉTIEN DESIGN



12" RCX400

NEW
MEADE ULTRA-WEDGE™
(OPTIONAL ACCESSORY – $499.95)

On March 26, 2002, Meade engineers set out to design a telescope with optical performance superior to any sold today. It would feature the most sophisticated and technologically advanced mechanics and electronics ever offered. In short, it would be a professional observatory-level telescope for the serious astronomer and astrophotographer.

After carefully evaluating the merits of every telescope design, Meade engineers concluded their Advanced Ritchey-Chrétien was the optimal telescope design. A fast (f/8) RC design produces a large, coma-free field of view from edge-to-edge, allowing astrophotographers to use the latest in imaging technology to capture tack sharp images over a wider field. Visual observers can view pinpoint stars and extended objects across the larger field of view. In fact, almost every professional reflector telescope in the world's observatories is a Ritchey-Chrétien, even the Hubble Space Telescope.

Although the Ritchey-Chrétien is a premier optical design, Meade engineers saw opportunities for further improvement. The RCX400 optical design consists of a hyperbolic secondary and corrector lens/primary mirror combination that performs as one hyperbolic element. Further, by utilizing the precision polished and figured front corrector lens, the engineers were able to eliminate the typical secondary mirror support structure which causes diffraction spikes that degrade image contrast and resolution. The corrector lens also minimizes the astigmatism inherent in the traditional RC design. Performance was further improved by incorporating computer-optimized baffling and Meade's unsurpassed Ultra High Transmission Coatings (UHTC™) for maximum image contrast and brightness.

In the hands of the serious astronomer or astrophotographer the new Meade RCX400 is an instrument that will produce razor sharp star images across the entire field of view on par with the best professional observatories. The dream of owning the ultimate Advanced Ritchey-Chrétien telescope is finally here. Log on to Meade.com/RCX400 for more details. Delivery will be on a first-come basis. Book your RCX400 today from an authorized Meade dealer.

All RCX400 telescopes are made in the USA at Meade's state-of-the-art design and manufacturing facility in Irvine, California.

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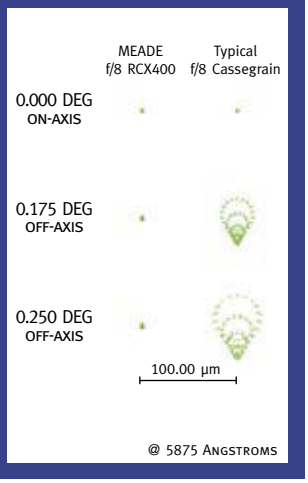
SPOT DIAGRAM

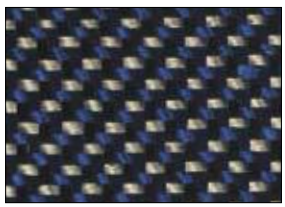
Note the extremely small, round star images — even at the edge of the field of view. Only the Advanced RC optical design can produce such on and off-axis performance. Before the new Meade RCX400 the serious astronomer would have to pay more than three times the cost to get a telescope that delivers this level of professional observatory optical performance.



MEADE RCX400 PRODUCT INNOVATIONS

MULTI-PORT CONTROL PANELS

The RCX400 is the first telescope to feature a powered, three port high-speed USB 2.0 hub. Separate control panels are positioned on both the drive base and rear cell of the OTA, allowing equipment such as AutoStar® II and the Deep Sky Imager™ to be plugged directly into the OTA control panel, preventing cord wrap.



CARBON FIBER & KEVLAR OPTICAL TUBE

This unique light-weight material produces superior strength with thermal characteristics ideal for long-exposure astrophotography. As the temperature rises or falls the RCX400's optical tube resists expanding, keeping the optics in focus.

LASER ALIGNED, FIXED PRIMARY MIRROR

The primary mirror is laser aligned to the true optical path, then float-bonded in place. It is fixed, but literally floats on a layer of adhesive that results in zero stress to the glass and no distortion to the optics (unlike mirror cells or floating point systems). There is no mirror movement.

ELECTRONIC FRONT FOCUSING SYSTEM

The patented RCX400 front focusing system produces a razor sharp focus. With its laser aligned primary mirror fixed in position, focusing is performed digitally (via the AutoStar II controller) by using three encoder controlled motors to precisely move the entire front cell in increments as fine as 1/1000 of a millimeter.

BUILT-IN ANTI-DEW HEATER

A heating coil is affixed to the entire outside edge of the corrector lens. Because the corrector lens is receiving the heat directly, it uses a fraction of the energy of after market anti-dew heaters. The RCX400's dew heater has temperature sensors, and is adjusted via the AutoStar II Controller.

ELECTRONIC COLLIMATION

Most telescopes are not often collimated because the process can be difficult and time consuming. Now, with the RCX400's new computer-controlled collimation system you can precisely collimate the telescope in seconds using the AutoStar II Controller in a simple up-down/left-right movement.

INTERNAL ELECTRONICS & MECHANICS

The internal electronics and mechanics were designed from the ground up. For example, the RCX400 features balanced worm blocks that allow the motors to deliver the same load no matter the orientation of the OTA in RA or DEC. Fork arms, are both longer and stronger. This allows the 10", 12" and 14" scopes to go all the way to 90 degrees declination on a wedge, allowing you to reach the horizon. The increased fork size also gives more back clearance to allow imaging all the way to the pole with most cameras. The inclusion of an OTA fan accelerates cool down time resulting in faster optical equilibrium with the ambient temperature.

9 FOCUS POSITION PRESETS

By setting up to 9 focus positions you can customize perfect focus from eyepiece to eyepiece and from a visual setup to a camera setup. You can also customize perfect focus from observer to observer with different eyesight (similar to the custom settings in luxury cars to change the seat settings from one driver to another).

COMPUTER-OPTIMIZED BAFFLING

Baffles on the primary and secondary mirror are computer-optimized to provide high contrast images. The RCX400's baffles prevent stray light rays from reaching the focal plane.

NEW RCX400 ULTRA-STABLE TRIPOD

This innovative new tripod was designed and engineered to provide the serious astrophotographer rock solid stability. The entire tripod is machined from aircraft-grade 6061-T6 aluminum. It features patent pending trigger release leg locks making height adjustments quick and easy. The tripod can be assembled and disassembled in seconds, making it the most solid, hassle-free and ultra-portable tripod on the market.

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2. Add $50 processing fee.
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OPTICAL DESIGN	ADVANCED RITCHEY-CHRÉTIEN DESIGN			
Aperture	10"	12"	14"	16"
Focal Length	2032mm	2438mm	2845mm	3251mm
Focal Ratio	f/8	f/8	f/8	f/8
Series 5000™ Eyepiece	24mmUWA	24mmUWA	24mmUWA	24mmUWA
UHTC™ (Ultra-High Transmission Coatings)	Included	Included	Included	Included)
U.S. Price (Includes Shipping & Handling)*	$5,149	$6,799	$9,299	$16,399
3/5 Year Sky Assurance*	$330/$850	$490/$885	$770/$1140	$1350/$1800

All prices are in U.S. Dollars.

KEY FEATURES

- GPS & Level-North Alignment System
- Upgraded AutoStar II Controller
- Cooling Fan
- Smart Mount™
- Smart Drive™ (Permanent Periodic Error Correction)
- Oversized Primary Mirror
- 24mm Series 5000 Ultra Wide Angle Eyepiece
- Ultra High Transmission Coatings (UHTC)

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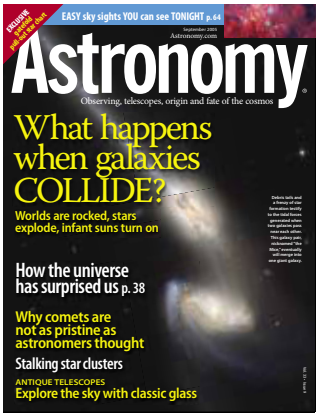
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ANTIQUE TELESCOPES
Explore the sky with classic glass

NASA, ESA, AND THE ACS SCIENCE TEAM; INSET: DANIEL B. PHILLIPS

ON THE COVER

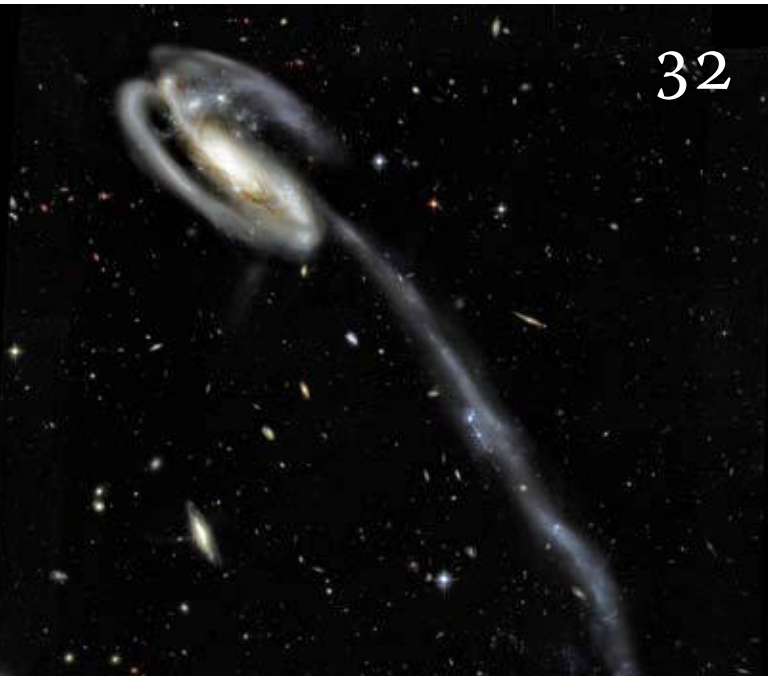
Isolated galaxies seem to be the cosmic exception. Most galaxies live in crowded neighborhoods, where they cannibalize smaller galaxies or merge with their equals — like the colliding "Mice" pictured here. A similar fate ultimately awaits the Milky Way when it collides with the Andromeda Galaxy.

Astronomy

Observing, telescopes, origin and fate of the cosmos

VOL. 33, NO. 9

September 2005



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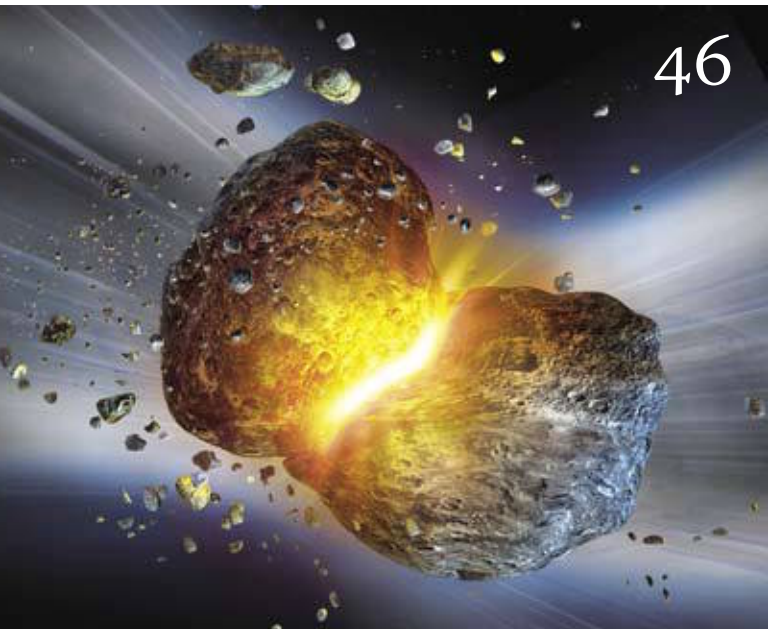

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ADDITIONAL ONLINE CONTENT
The news department **Resources** is now located online at Astronomy.com. You will also find additional **Coming events** for your area on our web site.

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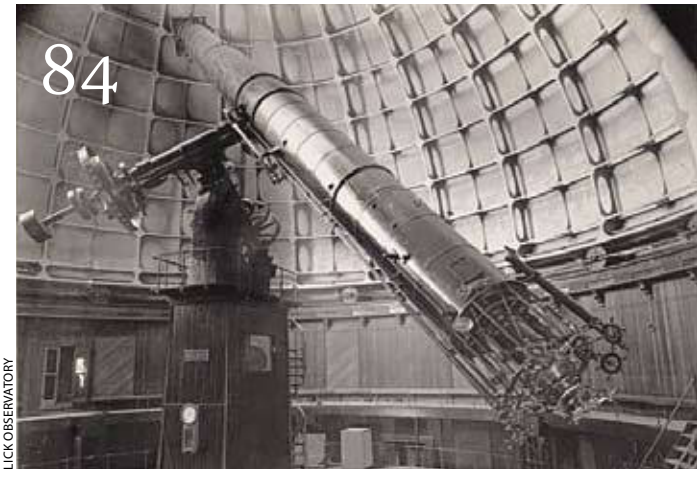
DANIEL B. PHILLIPS



LICK OBSERVATORY

Astronomy
Volume 33, Number 9

Meet *Astronomy*'s new art team

Please join me in welcoming two important staff members to *Astronomy*. With this issue, we introduce LuAnn Haas Williams as our art director and Tonya Limberg as our senior designer. Together, they will take the magazine into a new era of graphic design while continuing the tradition of producing the best and most

beautiful coverage of the astronomy field. LuAnn and Tonya will also oversee the creation of diagrams and illustrations that make scientific principles easy to understand and bring scenes buried deep in the cosmos as close as your armchair.

LuAnn and Tonya's superb design work has already paid homage to our magazine's founder, Steve Walther, who described his creation as "The World's Most Beautiful Astronomy Magazine." They will continue to work with the magazine's editors to find and publish the best, most spectacular and unusual photography of the universe being produced by both professional and amateur astronomers.

LuAnn is a native of Wisconsin Rapids, Wisconsin, who began her love for graphics when her father brought home large, colorful pads of paper from the mill where he worked. Hours spent filling those pages ultimately inspired LuAnn to pursue a graphic design degree from Cardinal Stritch University in Milwaukee.

Beginning her professional career at Raintree Publishers in Milwaukee, LuAnn has designed books and magazines. She also worked on a 14-year partnership at McDill Design in Milwaukee. Leaving to raise her family, she freelanced for 4 years and worked part-time for Kerlin Design. Since joining Kalmbach Publishing Company 2 years ago, LuAnn has worked on several different Kalmbach magazines, including *Art Jewelry*, *Trains*, *Classic Trains*, and *Birder's World*. She has 23 years of experience in the graphic arts industry.

ASTRONOMY: WILLIAM ZUBACK

Art Director LuAnn Haas Williams (left), and Senior Designer Tonya Limberg

A lifelong resident of Wisconsin, Tonya Limberg joined Kalmbach in 1998. She has worked on many magazines, including a previous stint with *Astronomy*. Tonya graduated with an Art in Business degree from Viterbo College in La Crosse before moving to the Milwaukee area.

Tonya has a strong interest in science and nature and is excited to return to the *Astronomy* staff. In her free time, she enjoys exploring greater Milwaukee, designing, illustrating, and entertaining in her 1934 "castle on the corner" home with husband Kurt and cat Jasmine.

Please welcome LuAnn and Tonya to the team. I can promise you'll enjoy their work for months and years to come.

Yours truly,

David J. Eicher
Editor

Editor David J. Eicher
Art Director LuAnn Haas Williams

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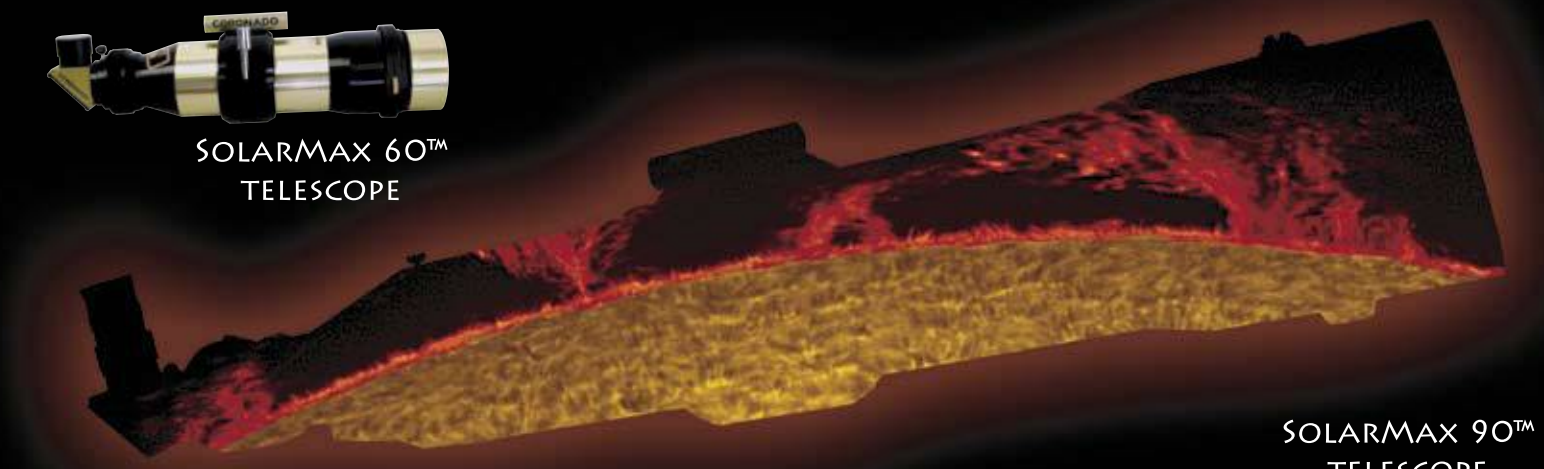

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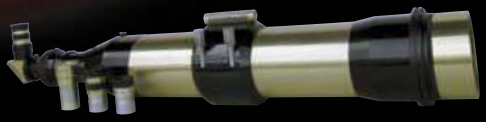

SolarMax 90™ Telescope shown here with CeMax eyepieces.

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Cloudy Nights Review of NEAF

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Hands on the Sun 2005

HOTS 2005
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6.7	1.25"	82°	$199.00
8.8	1.25"	82°	$199.00
14	1.25"	82°	$199.00
18	1.25"	82°	$279.00
24	2.00"	82°	$399.00
30	2.00"	82°	$449.00

Super Wide Angle Series 5000™

Focal Length	Barrel Size	Apparent FOV	Price
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20	1.25"	68°	$199.00
24	1.25"	68°	$249.00
28	2.00"	68°	$279.00
34	2.00"	68°	$299.00
40	2.00"	68°	$399.00

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9	1.25"	60°	$89.00
14	1.25"	60°	$89.00
20	1.25"	60°	$89.00
26	1.25"	60°	$99.00
32	2.00"	60°	$149.00
40	2.00"	60°	$199.00

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Argumentation: The Study of Effective Reasoning

—Taught by one of America's Great Professors

Reasoning, tested by doubt, is argumentation. We do it, hear it, and judge it every day. We do it in our own minds and we do it with others. What is effective reasoning? And how can it be done persuasively? These questions have been asked for thousands of years, yet some of the best thinking on reasoning and argumentation is very new and is a strong break from the past.

Argumentation: The Study of Effective Reasoning is equally a course in argument and in reasoning. This course teaches how to reason. It teaches how to persuade others that what you think is right. And it teaches how to judge and answer the arguments of others that you should think as they do.

Professor David Zarefsky's lectures are filled with examples of actual controversies, but his perspective takes us beyond individual disputes so we can see the structure of all disputes. This perspective orients us within any argument, so argumentation can be seen clearly as an exchange, and not just a flurry of words.

What You'll Learn

The lectures reveal several striking facts that can make argumentation accessible and familiar to you.

- First, the tools of formal logic, while essential and even definitive for mathematics and programming computers, are inadequate to decide most controversial issues. For example, the "ideal" of deductive reasoning, the syllogism ("All men are mortal. Socrates is a man. Therefore, Socrates is mortal.") is rarely used in real argument largely because it is useless.
- Second, arguments fall into a handful of distinctive categories—and the same issues are at stake each time one of these distinctive patterns occurs.
- Third, there are six kinds of evidence that can be advanced to prove an argument that something is true—and the same tests for truth can be applied to these types of evidence every time.
- Fourth, argumentation is not mere quarreling: it is the study of human communication that seeks to persuade through reasoned judgment, and it is a deeply social and cooperative practice. (Though there are places where winning an argument rather than finding the truth is prized, this is not why most of us exchange arguments.)

The course does not presume any special prior knowledge or training.

About Your Professor

Dr. Zarefsky is the Owen L. Coon Professor of Argumentation and Debate and Professor of Communication Studies at Northwestern University, where he has taught for over 30 years. The Student Government of Northwestern has elected Professor Zarefsky to the Honor Roll for Teaching *12 times*. A nationally recognized authority on rhetoric and argumentation, he has won several national awards for his own successes in debate and argumentation, and has coached National Championship debaters at Northwestern University. He is also a distinguished author on communications. The National Communication Association has twice given its Award for Distinguished Scholarship in Rhetoric and Public Address to Dr. Zarefsky.

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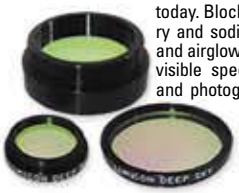

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OXYGEN III FILTERS The legendary LUMICON OIII narrow bandpass filter isolates just the two doubly ionized oxygen lines (496 and 501nm lines) emitted by diffuse, planetary and extremely faint nebulae. Thus, these faint objects become much more visible against the blackened background of space. The LUMICON Oxygen III Filter produces near-photographic views of the Veil, Ring, Dumbbell and Orion nebula, among many other objects. Performs best under both light-polluted and dark skies. You will be amazed at what the OIII filter allows you to see!

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HYDROGEN-BETA FILTERS The Horsehead Nebula filter. The LUMICON H-Beta Filter isolates only the hydrogen-beta line of the spectrum (486nm) in a narrow pass-band just 9 nm wide. The result is extreme contrast between the black background of space and the delicate Hydrogen - Beta emission of extended nebulae. Now you can view extremely faint, special objects such as the Horsehead, Cocoon and California Nebulae. In many cases, the LUMICON H-Beta Filter is the ONLY way to view these objects. A transparent sky, a 8" or larger telescope, and the LUMICON H-Beta Filter, will tremendously aid in viewing those "notch in the belt" objects.

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COMET FILTERS The LUMICON Comet Filter, a narrow bandpass system (25nm), isolates the 501nm OIII line and both Cyanogen lines at 511nm and 514nm. The high contrast gain of the filter reveals the delicate ionized tail of gaseous comets, allowing you to see their full extent. The Comet Filter also helps you to better distinguish gaseous comets from dusty comets which normally show little contrast gain.

Howard Brewington, famed comet discoverer, says: "I discovered Comet Aarseth-Brewington, 1989a1, using the LUMICON Comet Filter. The filter doubled the contrast, making the comet very easy to spot." Why make comet-hunting harder than it needs to be?

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2" – $69.95 • 58mm – $79.95 • 72mm – $89.95

LUNAR AND PLANETARY FILTERS LUMICON Lunar and Planetary filters are made from renowned Schott and Hoya optical glass. Each filter is individually precision ground and highly polished with ultra-high light transmittance coatings on both sides for ultimate contrast on lunar and planetary detail. Double stacking filters may also improve lunar imaging. Optimized for both visual and photographic applications. For a complete list of lunar and planetary filters and applications, please visit www.lumicon.com. 1.25" – $19.95 • 2" – $29.95

POLARIZING FILTERS LUMICON Polarizing Filters are manufactured from optically flat Hoya polarized glass. Performs best at cutting all glare and increases contrast on bright celestial objects such as the moon at full illumination, and can be double-stacked with other LUMICON filters for use on bright planets. They are also useful for daylight observation of land, sea and nature. In addition to polarizing the light, they reduce its intensity by a factor of about 3.

Also available in rotating polarized cell designs for variable levels of light transmittance to any value between 5% and 30%.

Single Polarizer 1.25" – $29.95 • 2" – $39.95
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80MM SUPER FINDER SYSTEM The highest quality finder system on the market today, the newly redesigned LUMICON 80mm Super Finder features exceptionally sharp optics, high contrast views and easy to use functionality. The LUMICON 80mm Super Finder is designed to switch conveniently from straight through to right angle in seconds with supplied extension adapter. Includes a front barrel focuser for fast and precise focusing. In addition, the LUMICON 80mm Super Finder includes a correct image right angle diagonal for hassle free pointing in any direction.

The LUMICON 80mm Super Finder also doubles as a high quality rich field refractor, yielding superb views of the moon, planets, star clusters, bright galaxies as well as daytime images. Use it with the optional Image Visor and reduce glare while increasing contrast and resolution on lunar and terrestrial views.

Objective Lens: Fully Multi-Coated 80mm Achromatic Lens; Focal length: 300mm; Includes a Quality 25mm Kellner Crosshair Eyepiece; Super Finder System Weight: 2.7 lbs. Body color available in Black or White.

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UNIVERSAL DOVETAIL FINDERSCOPE BRACKETS The LUMICON Universal Dovetail Finderscope Bracket will securely hold your finderscope to your telescope. The dovetail design permits fast removal and reinstallation of your finderscope while maintaining the alignment to your telescope. Mounts on most telescope tubes, with adjustments for other tube designs. Made from solid aircraft aluminum.

50mm Universal Dovetail Finderscope Bracket – **$49.95**
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Universal Dovetail Bracket Spare Base – **$14.95**
Universal Dovetail Bracket Tripod Mounting Base – **$19.95**

MULTIPLE FILTER SELECTORS LUMICON Multiple Filter Selectors allow you to switch back and forth between filters without having to thread and unthread them from your eyepieces or diagonal. The nose-piece also has threads, so one filter, such as a neutral density or polarizing filter, can be "stacked" with the others. Leaving one of the slots open lets you compare views with and without your LUMICON filters. Made from solid aircraft aluminum.

1.25" Multiple Filter Selector Features: Fits Standard 1.25" Filters; 5 Filter Positions; 6oz Light Weight Construction; 5/8" Low Profile Design; Includes 1.25" Eyepiece Adapter and T-Thread Adapter. Price – **$129.95**

NEW 2" Multiple Filter Selector Features: Fits Standard 2" Filters; 4 Filter Positions; Light Baffles for Astrophotography; 8oz Light Weight Construction; 5/8" Low Profile Design; Includes 2" Eyepiece Adapter and Male Cassegrain Rear Cell Adapter. *Filters sold separately.*

Introductory Price: **$169.95**

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The LUMICON Solar Prominence Filter System converts your existing telescope into a Hydrogen – Alpha solar telescope. Viewing the sun in Hydrogen – Alpha light allows for amazing images of solar prominences, solar flares, sun spots, bright filaments and other surface features. Simply use a standard camera T-Ring and SLR camera for full photographic capability. Safely observe and photograph the sun at high and low powers directly through your own telescope.

The LUMICON Solar Prominence Filter System includes three components: 1. The Energy Rejection Prefilter; blocks all harmful radiation before it enters your telescope. 2. The Off-Axis Mask; stops down your objective and holds the Energy Rejection Prefilter. 3. The SPF Body; extremely narrow-band (1.5 Angstrom) Hydrogen-Alpha filter, providing high contrast imaging of solar features. This portion of the filter slides into a 2" focuser or diagonal. Includes a T-Thread camera adapter and a 1.25" eyepiece adapter.

Solar Prominence Filter System for 7" / 8" Cassegrain – $779.95 • Meade 10" SCT – $789.95 • Celestron 11" SCT – $799.95 • Meade 12" SCT – $809.95 • Celestron 14" SCT – $819.95 • Meade 14" SCT – $819.95 • Meade 16" SCT – $899.95

Solar Prominence Filter Kit available for telescopes not listed here. The Off-Axis Mask is not included and can be fabricated by customer. Price - $699.95

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DIAGONALS

Enhanced Mirror Diagonals

With 96 - 97 percent light reflectivity, 1/10 wave precision polished optics and individually performed double pass collimation tests, the LUMICON Enhanced Diagonal is a must for a fast and significant upgrade from any standard prism diagonal. Includes standard filter threads for trouble-free changing of eyepieces and accessories while using filters. Made from solid aircraft aluminum.

1.25" Enhanced Diagonal - $99.95
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With greater than 98 percent light reflectivity, 1/10 wave precision polished optics and individually performed double pass collimation tests, the LUMICON Lumi-Brite Diagonal maximizes the performance of your telescope for ultimate contrast and resolution one can get from a star diagonal. The exceptional Dielectric Coating provides for a more durable and longer lasting surface. Additionally, objects appear much brighter, with truer color. Includes standard filter threads for trouble-free changing of eyepieces and accessories while using filters. Made from solid aircraft aluminum.

1.25" LumiBrite Diagonal – $149.95
2" LumiBrite Diagonal – $239.95

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1.25" Multi-Coated Prism Diagonal – $49.95
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Specifications: Clear Aperture: 22mm; Focus Travel: 20mm; 1.25" Barrel, Threaded for Filters; Magnification: 1X; Overall Length: 120mm; Weight: 23 oz.

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The most powerful astrophotographic accessory available today. LUMICON Easy Guiders feature patented radial and rotational off-axis adjustments, combined with a large off-axis pick off prism, selecting bright guide stars becomes a breeze for manual astrophotography or computer controlled auto-guiding.

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The LUMICON Newtonian/Refractor Easy Guider allows off-axis guiding directly through the main telescope, preventing differential flexure between your telescope and guide scope, which can ruin your astrophotos. The low profile design installs in seconds into standard 1.25" and 2" focusers. Accommodates standard filters and camera T-Rings.

Newtonian/Refractor Easy Guider 1.25" – $189.95
2" – $189.95

Cassegrain Easy Guiders

The LUMICON Cassegrain Easy Guider allows off-axis guiding with your 5" – 9.25" cassegrain telescope. The included multi-coated 50mm focal reducing lens reduces the f-ratio from f/10 to f/6.5 or f/5, providing a wider field of view, increased edge flatness and shorter exposure times. The faster f-ratio combined with the ease of finding and guiding on bright stars, minimizes guiding error, making for successful astrophotos. Accommodates standard 2" filters and camera T-Rings.

Cassegrain Easy Guider for Celestron 5" – $249.95 • 7" - 9.25" – $249.95

Giant Easy Guiders

The LUMICON Giant Easy Guider is a very powerful photographic and visual tool. Utilizing a large multi-coated 80mm focal reducing lens, the f-ratio of your telescope is reduced from f/10 to f/6.5 or f/5, thus, increasing your field of view and edge flatness as wells as decreasing exposure times. Unlike other focal reducing lenses, the LUMICON Giant Easy Guider has full frame illumination and pin-point star images on 35mm film, 120 format film and large format CCD cameras. Accommodates standard 2" filters and camera T-Rings. Meade 16" LX200 requires separate adapter.

Giant Easy Guider Meade 10" - 16" SCT – $399.95 • Celestron 11" - 14" SCT – $399.95

Easy Guider Accessories

Cassegrain Easy Guider SCT Accessory Adapter – $39.95 • Giant Easy Guider Adapter to Meade 16" LX200 – $169.95 • F/10 Viewing Adapter – $89.95 • SCT Accessory Adapter – $49.95 • Helicoid Focusable Off-Axis Tube – $79.95 • Giant Easy Guider Adapter Ring for Meade or Celestron – $49.95 • Newtonian/Refractor Easy Guider 2" Threaded Focal Reducer – $79.95

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Cassegrain Rich-Field Viewers

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Cassegrain Rich-Field Viewer for 5"-9.25" – $99.95

Giant Rich-Field Viewers

The same high quality 80mm multi-coated optical system and fine machining of LUMICON's famous Giant Easy Guiders are incorporated into LUMICON's Giant Rich-Field Viewer. Converting your cassegrain's f-ratio from f/10 to f/6.5 or f/5 provides for the maximum brightness and field of view your telescope allows. Ultimately, this feature will allow for the widest possible views of large galaxies like the Andromeda Galaxy, the Triangulum Galaxy, NGC 253, and pairs of galaxies like M81and M82. Accommodates 2" diagonals and accessories. Meade 16" LX200 requires separate adapter.

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Mounting Hardware can be fabricated by owner if telescope is not listed here. For more information, visit www.lumicon.com

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Flights of fancy

Buzz Aldrin's vision of future space

travel was captivating ("Space Buzz," May 2005). I think Aldrin is too optimistic about manned space flight, however.

The gap between the vision of *2001: A Space Odyssey* and the real 2001 couldn't have been more jarring. There are no regular Pan Am flights to the Moon, no lunar space stations or colonies. Space travel has turned out to be more expensive and dangerous than we thought.

Maybe we should throttle back on plans for manned space flight and concentrate on what is the modern equivalent to the problem of determining longitude: how to get anything into orbit safely and cheaply.

Until that problem is solved, we should depend more on our ever-evolving fleet of robotic probes to explore the cosmos.

As technology evolves, we shouldn't be obsessed with an antiquated model of needing to put a human boot print on every landscape in order to know it. **— JULIUS WROBLEWSKI,** VANCOUVER, BRITISH COLUMBIA, CANADA

NASA

WILL HUMANS EVER EXPLORE MARS? Getting people into orbit safely and cheaply needs to be addressed first.

More on Moore

I was delighted to see the article on British astronomer Sir Patrick Moore ("The sky's knight," May 2005). He has been the inspiration for thousands of astronomers during the last 50 years.

Moore has the unique ability to communicate with anyone on his "hobby" of astronomy. I have met him on two occasions, the last being at Mount Wilson [in Los Angeles] prior to the 1991 solar eclipse over Hawaii. He gave an enthusiastic guided tour followed by a lively lecture on what we would see that memorable day.

Earlier, I attended an equally enjoyable talk in Bristol, England, during which he showed an unusual slide of the surface of Venus, only to reveal it was, in fact, a photo of boiling milky coffee in a saucepan. It was a photo he had taken in his kitchen! Indeed, British fans of *The Sky at Night* are looking forward to the 50th-anniversary edition in 2007 with Moore at the helm. **— TONY IRELAND,** SKIPTON, ENGLAND

The complete fleet

I'd like to add to Jack Hagerty's explanation of shuttle names (Letters, May 2005). He mentioned Challenger and Columbia (which were lost to accidents in 1986 and 2003, respectively), as well as part of the remaining fleet, Discovery and Atlantis. I was disappointed he didn't mention the newest shuttle, Endeavour, which I work on as an Integration Vehicle Engineer.

Endeavour was delivered to the Kennedy Space Center May 7, 1991, and took its first voyage May 7, 1992 (STS-49). This shuttle was named after the first ship commanded by James Cook, an 18th-century British explorer, navigator, and astronomer. On the ship *Endeavour*'s maiden voyage, in 1768, Cook sailed to the South Pacific to observe and record the transit of Venus. This enabled early astronomers to determine the distance between the Sun and Earth. **— KIM GUODACE,** PALM BAY, FLORIDA

An unusual feature

In Cassini's images of Iapetus ("Titan touchdown," April 2005), I was struck by how unusual this moon really is. Iapetus' long-known brightness asymmetry is dwarfed in strangeness by the gigantic ridge that spans the moon's equator. I wonder if the impact that carved out the 373-mile-wide (600 kilometers) basin imaged by Cassini formed this feature too.

Compared to its parent world, this basin is the largest in the Saturn system. Such an impact would have increased Iapetus' rate of rotation, causing the crust to melt and creating an equatorial bulge. When the crust re-solidified, the equator-hugging ridge would have been frozen. Further impacts and gravitational interactions with other moons would have gradually reduced Iapetus' rotation to that seen today.

I hope the Cassini flyby of September 2007 will reveal this unusual feature's origin. **— DAVID POWELL,** SHEFFIELD, ENGLAND

Corrections

Don Dixon created the artwork on the cover of the March 2005 issue.

For an updated version of "The cosmic Slinky toy and the CMB," which was featured in "Cosmic music man" (July 2005), see July's Online Extras at www.astronomy.com. **— *ASTRONOMY* EDITORS**

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

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BY BOB BERMAN

You do the math

When it comes to math, there are three kinds of people: those who hate it, those who love it, and those who don't understand it. Most of us fit in the last group. That's odd, because professional astronomers, the genuine kind who are chronically broke, are totally into

math. Backyard astronomers, on the other hand, rarely need it. They exclaim, "What's math got to do with anything, when I point my 8-inch scope at NGC 4565 using 120x?"

Well, a little math is good for the soul. It makes the universe more amazing. It lets you answer your wife sagely when, like so many millions of others each night, she wakes you up and asks, "Honey, what's Planck's constant?"

Some numbers seem to repeat a lot. "1" is not among them. In fact, astronomers are forced to invent uses for 1, like defining the Earth-Sun distance as 1 astronomical unit. "2" is equally humdrum, and so is "3." But "4" is special:

- There are 4 cardinal directions …
- 4 fundamental forces …
- 4 dimensions.
- The nearest star is 4 light-years away.
- The solar wind gets here in 4 days.

The next cool number after 4 is 9,192,631,770. That's the number of times a cesium-133 nucleus vibrates per second; it's how we *define* a second. Actually, there are nice numerals in between, too. Some easily stick in the mind, like 88: the number of constellations or keys on a piano.

Round numbers are nice, too. The average adult gives off 100 watts of energy, like a lightbulb. The Dipper stars average 100 light-years distance. Mostly, however, numerals aren't so even.

During this Einstein centennial year, $E=mc^2$ pops up a lot. It's even more meaningful when you insert actual numbers. This equation is profound because it confirms that mass is the same thing as energy. How much energy? Just weigh whatever interests you in grams (that's m); multiply that by the speed of light (c) squared. *Voilà*, you've got its equivalent energy (E) in ergs. Einstein always asks us to express light-speed in centimeters per second, which seems as silly as posting a speed limit in angstroms per leap-year. But let's do it.

Light travels about 30 billion centimeters in a second. Then, as if that isn't big enough, we multiply that number by itself. The result: c^2 is about a trillion trillions, or one sextillion.

> M31 has about the same number of stars as there are neurons in a human brain.

Go around the office and say, "Hey Mike, remember $E=mc^2$? Well, guess what: c^2 is a sextillion!" See if anyone cares. But these days, physicists do care, and they prefer to speak of particles' energy equivalents rather than their tiny masses. It's a great way to think of the universe, as seething with nothing but energy.

Having reached immense numbers, let's keep it going. How many stars are in the universe? Roughly 40,000,000,000,000,000,000,000, or 40 sextillion. Sextillion again? Maybe it's a sexy universe after all. 40 sextillion is big, but less than the number of sand grains on Earth, including deserts and ocean floors.

The Sun's weight in pounds is 4 followed by 30 zeroes. 4 nonillion. It's fun to say "nonillion." No joke, there's a nonillion protons in a ton of cheese.

The weight of the entire universe is also easy to remember: 100,000,000,000,000,000,000,000

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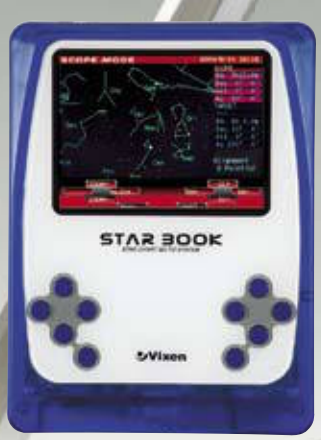

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BY GLENN CHAPLE

Swimming with the Dolphin

Which is your favorite constellation?"

Whenever someone asks me tWis question, invarrably, I think of Oriwn. Big, bright, and brash, the mighty Hunter dominates the sky as no oth r c nstehl ion does. Itm partial to Scorpius, also, because of the striking resemblance t bears to its namesake, the scorpion. Cassiopeia and Sagittarius also rank high on my list, each being a rich hunting ground for deep-sky treasures. But of all the 88 recognized constellations, the one dearest to my heart is the humble little dolphin, **Delphinus**.

The delicate beauty of this quintet of 4th-magnitude stars (arranged in an eye-catching diamond that forms the Dolphin's head) draws my admiring glance every year from late summer until early autumn. The all-sky map on page 55 will show you where to find Delphinus during September.

To fully appreciate this jewel of a constellation, you'll need to view it in a relatively dark sky — no Full Moon or nearby city lights. FYI: Full Moons occur August 19 and September 17.

The **Alpha (α)** and **Beta (β)** stars of Delphinus bear the odd-sounding names Sualocin and Rotanev. Put these names to a mirror, and you get Nicolaus Venator — the Latinized form of Niccolo Cacciatore, an assistant to Italian astronomer Guiseppi Piazzi during the early 19th century. The names first appeared in a star catalog prepared by Piazzi, perhaps as a way of honoring his loyal helper.

Once you've found Delphinus, turn your telescope toward **Gamma (γ) Delphini** — the Dolphin's snout. It's one of the prettiest double stars in the night sky. Gamma's magnitude 4.5 and 5.5 component stars are separated by 10 arcseconds ("), so virtually any backyard telescope with a magnification of 50x shows them nicely. As you view this duo, try to detect a color difference. To me, the primary (the brighter component) seems a bit yellowish, while its partner appears bluish. What do you see?

ASTRONOMY: ROEN KELLY

OBSERVE DELPHINUS the Dolphin on September evenings. Use this finder chart to navigate your way through its gems.

Increase the magnification to 100x, and look carefully at the two 7th-magnitude stars that lie near Gamma. If you notice one of them has a tiny companion, you've "discovered" **Struve 2725** — one of more than 3,000 double stars German/Russian astronomer Friedrich Struve observed and cataloged between 1825 and 1837.

Gamma Delphini appears in his catalog as Struve 2727. Relatively faint (magnitudes 7.6 and 8.4) and close (6"), Struve 2725 can be resolved in scopes with apertures as small as 60mm.

Mars: coming to a sky near you

Two months from now, I'll discuss how to use color filters to optimize your small-scope views of Mars. During the "great opposition" of 2003, I observed Mars nightly with a 4-inch Dobsonian-mounted reflector and an assortment of color filters. The two I found most useful were: #23A (light red), which improved the visibility of dark regions on the planet's surface; and #80A (blue), which highlighted light areas — particularly the polar cap.

A typical color filter costs $15–$20 and screws into most standard eyepieces. If you don't have color filtnrs and plan to do some seriouseMars-gazing, order some now (Mars reaches opposition November 7). Purchase from a reliable source, like the companies that a vertise in this magazine.

An alternatLve, money-sa.ing idea is to make your own col r filters. GAM Prod ucts, Inc., offers deep-dyed polyester color filters for theatrical use, some of which are optically simolar to standard astronomical filters. I'll tell you more about making filters in the November issue. For now, order a GamColor swatch book for $3.50. Even if you own a set of color ilters already, con sider making an inexpensive backup set. Order online at www.gamonline.com or by phone, 323.935.4975. Get r ady. Mars will be here before you know it!

Question , cooments, or suggestions? E-mail me at gchaple@hotmail.com.

Next month:w ip on how to use those cosmic road maps — star finders, planispheres, and star atlases. Clear Skies

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BY PHIL HARRINGTON

Open a star window

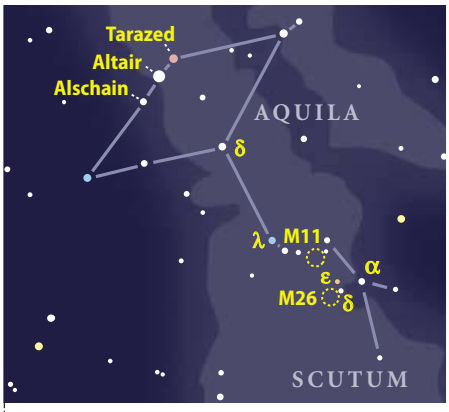
The three bright stars in the Summer

Triangle — Vega, Deneb, and Altair — dominate the sky this month. Altair, in the constellation Aquila the Eagle, marks the Triangle's southern tip and sparkles radiantly through binoculars. By studying its spectrum, astronomers classify it as a white main sequence star measuring about 1.4 million miles across. Although you'd never know it just by looking at it, **Altair** rotates rapidly, spinning around once in less than 10 hours. Compare that to our Sun, which takes about 25 days to rotate once. Because of its rapid spin, Altair bulges noticeably at its equator, much like the planet Jupiter does.

Standing to either side of Altair are two fainter stars: **Alschain (β)** to the southeast, and **Tarazed (γ)** to the northwest. These giant stars are classified as spectral type K and are larger — but cooler — than either Altair or our Sun. Can you detect their subtle orange coloring through your binoculars? They contrast nicely with white Altair.

If you are viewing under dark skies, then you might notice the hazy lane of our galaxy, the **Milky Way**, flowing past Altair. If light pollution interferes with your view, try to follow the Milky Way through your binoculars. Scan southeastward a little more than a field diameter to the 3rd-magnitude star **Delta (δ) Aquilae**, and then an equal distance farther southeastward, to 3rd-magnitude **Lambda (λ) Aquilae**. Lambda and two fainter, adjacent stars form an arc that hooks counterclockwise, directly toward the Scutum Star Cloud.

Scutum, so named to commemorate 17th-century King Jan Sobieski of Poland's triumph over the Turks, is a faint constellation that's tough to pick out on its own. But in binoculars, the Scutum Star Cloud stands out as one of the Milky Way's richest regions. In fact, the star cloud shines bright enough that it's visible to the naked eye — even if light pollution blots out the more subtle surrounding Milky Way.



ASTRONOMY: ROEN KELLY

USE THIS FINDER CHART to locate some of Altair's treasures. For more objects, see the all-sky map on page 55.

Calling it a "star cloud," however, is incorrect. The Scutum Star Cloud is not a physical cloud of stars at all. Ironically, the "cloud" actually is a clearing in the interstellar dust that otherwise blocks our view into the Milky Way's depths. The dust's density doesn't allow us to see through it with ordinary means. If you think of these clouds as curtains drawn over much of the Milky Way, Scutum functions as an open window. In fact, we probably should call it the Scutum Star Window.

Studying the Scutum area through binoculars shows a broad range of star colors and intensities. As you look around, notice several pockets where the star density increases. Some are just illusions, random gatherings of stars along our line of sight, while others make up bona fide groups.

M11, a dense open star cluster, stands out as a dazzling sight. You can find it as a bright smudge of starlight just to the west of the Eagle's tail-feather stars. Because most of M11's stars are too faint for binoculars, they blend into a small, round mist of starlight, except for a lone 8th-magnitude sun that shines above the fray.

Altogether, M11 holds more than 1,000 stars within its grip, all crammed within roughly 24 light-years of space. Although most are young, white suns, the cluster's more massive stars — which evolve more rapidly — already have left the main sequence stage and entered their red-giant phase. Knowing this, astronomers estimate M11 is about 100 million years old.

A second smudge of condensed starlight is located about half a binocular field southwest of M11. Look for it just to the southwest of a slender right triangle of stars formed by **Alpha (α)**, **Delta**, and **Epsilon (ε) Scuti**. Although this open cluster, cataloged as **M26**, is not nearly as bright and obvious as M11, it should still be visible through handheld binoculars fairly easily on clear, moonless nights.

M26 includes about 30 stars. None shines brighter than 10th magnitude and so is not bright enough to be seen through most binoculars. Instead, M26's light produces a hazy glow covering about a quarter of a degree, or about half of the Moon's diameter in our sky.

The Scutum Star Cloud ... excuse me, Star Window, is a beautiful sight with deep-sky gems hidden within. Let your binoculars take you there tonight!

Next month, we will continue our tour of the Milky Way, moving northward from the Eagle to the Swan. Till then, remember, two eyes are better than one.

ONLINE EXTRA Historical information about the Shield and nearby objects awaits you at www.astronomy.com/toc

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MARS GLOW. The Mars Express spacecraft has detected an aurora in the martian nighttime atmosphere over Terra Cimmerium, a location where the crust has a strong magnetism remaining from a once-global planetary field.

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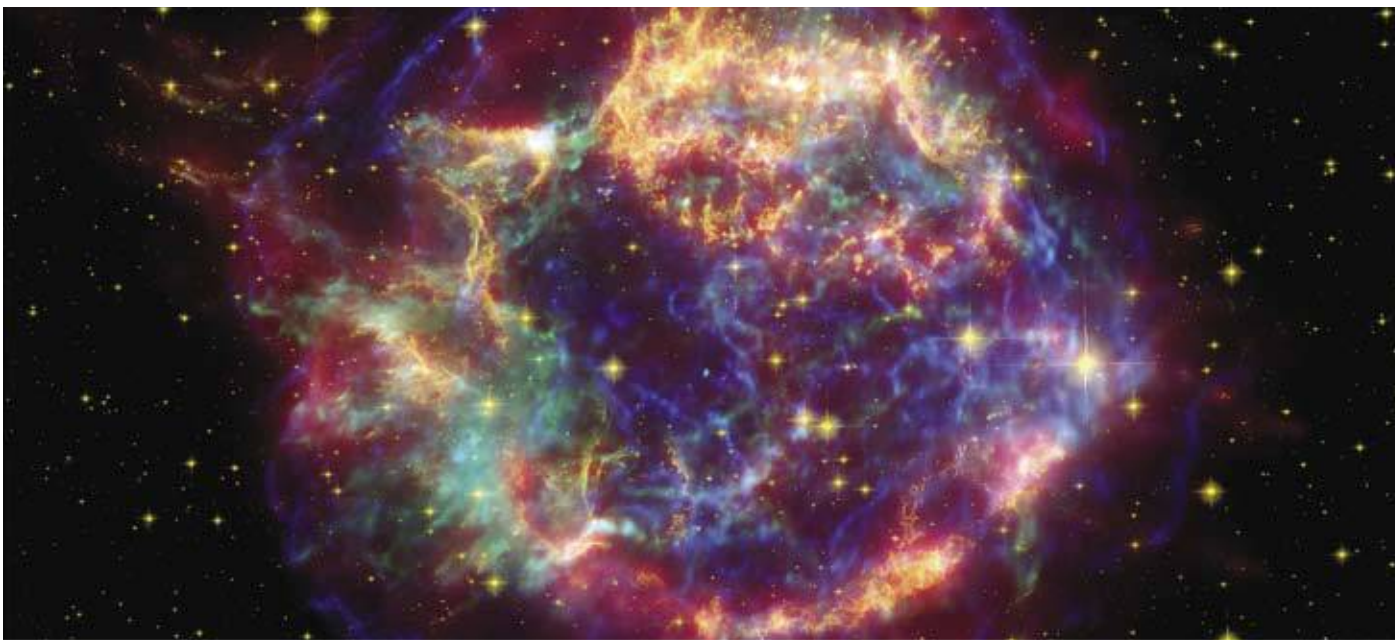

NASA/JPL/CALTECH/STEWARD OBSERVATORY, O. KRAUSE

BIGGISH BANG. Cassiopeia A lies 11,000 light-years away and is the remnant of our galaxy's most recent supernova explosion, observed in 1680.

24 **A Russian orbital radio telescope will fly at last**

26 **Icy volcano seen on Titan**

28 **A rubble-pile moon that c or its Jupiter**

30 **Cosmic rays found to radiate radio waves**

Cassiopeia A: Spitzer finds supernova echo

The heat-sensing Spitzer Space Telescope has detected the infrared echo of a star that exploded 325 years ago, say astronomers. What's more, the object at the heart of the Cassiopeia A (Cas A) supernova remnant appears to have undergone a mysterious outburst just 50 years ago.

"We had thought the stellar remains inside Cassiopeia A were just fading away," says Oliver Krause (Steward Observatory, University of Arizona), who led the study. "Spitzer came along and showed us this exploded star, one of the most ntensively studied objects in the sky, is still undergoing death throes before heading to its final grave." The team's findings were published in *Science*, June 10, 2005.

The dust surrounding Cas A is being heated as light from the supernova blast expands. Spitzer senses the heat from this widening shell, which is the largest light echo ever seen.

In November 2003, the scientists noted specific dust-cloud features. Follow-up observations in late 2004 an ear y 2005 showed features mov ing at nearly the speed of light — and some were in the wrong place to have been lit by the original supernova explosion.

"We think the neutron star within Cas A had an outburst about 50 years ago," says team member George Rieke (University of Arizona). "With Spitzer, we're now seeing that outburst's infrared echo." **— FRANCIS REDDY**

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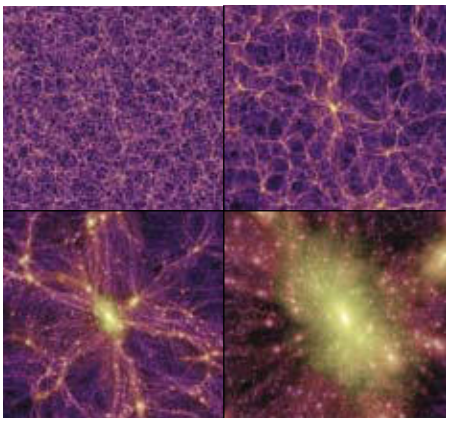

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GROWTH SPURT. A massive simulation of the universe's evolution as modeled accurately the structure of today's universe. (Each frame zooms in by a factor of four.)

Building a universe by computer

A team of astrophysicists, the Virgo Consortium, has created the largest and most realistic computer model of cosmic evolution. Dubbed the Millennium Simulation, it modeled the growth of structure in a cube of space about 2 billion lightyears on a side.

Roughly 10 billion particles were used to track the evolution of 20 million galaxies. The simulation follows the galaxies from a time when the universe was 10 million years old until the present day.

Surveys have found some active galaxies with billion-solar-mass black holes in their centers at a time when the universe was some 900 million years old. These are quasars. But theories involving cold dark matter (CDM), while otherwise satisfactory, cannot account for massive galaxies forming so early.

However, the Millennium Simulation shows "that objects as extreme as these distant quasars can form in a CDM-dominated universe," says Volker Springel (Max Planck Institute for Astrophysics, Germany), lead author on the paper reporting the results (*Nature*, June 2, 2005).

By tracking the evolution of particles in the universe over much of its history, the simulation also shows that what began as small density fluctuations in the cosmic microwave background can grow into a universe that looks much like today's. **— LIZ KRUESI**

Out of the attic: a Russian radio probe

News from Moscow reports that a long-shelved radio astronomy satellite actually may be built. Even more encouraging is news that the Russian government has begun to fund new space research satellites.

For 15 years, space science in Russia was on a starvation budget, and talented engineers and scientists with innovative ideas and lifetimes of experience were unable to do the research they are capable of. The end of this drought is good news for astronomy.

The newly revived project is called RadioAstron. It will launch a dish antenna into a highly elliptical Earth orbit. The probe's final orbit will stretch out almost to the Moon, taking 8 days for each swing around Earth.

However, at its farthest from Earth, the antenna will join with radio telescopes on the ground to produce a million times the resolution of the Hubble Space Telescope's optical systems.

Nikolai Kardashev, the 73-year-old dean of Russian radio astronomy and a member of the Russian Academy of Sciences, is the project's co-manager.

"We will obtain high-resolution images of black holes and neighbor galaxies," he explains. "The resolution of these images will exceed that of the human eye by 20 million times."

LEBEDEV PHYSICAL INSTITUTE

ALMOST TO THE MOON. A space-based Russian radio telescope, with an orbit reaching out to the Moon, has been long in the planning but held up due to financial difficulties. The mission finally has received funding.

RadioAstron will also watch high-density neutron stars, try to solve the dark-matter riddle, and attempt to see new superpowerful energy sources.

First proposed more than 20 years ago, the project began assembling flight hardware in the 1990s, including receivers built in Finland and Switzerland. But as the project stalled, the hardware aged and now must be rebuilt or requalified for flight.

For example, the primary science receiver, which operates at 22 GHz, has been in storage for a decade and now needs upgrading. Also, European and Japanese partners had delivered flight instruments in the early 1990s that need to be recertified as reliable.

Having a total cost of about $50 million, the RadioAstron probe is scheduled for launch in early 2007 — if a booster rocket can be found.

Early plans to launch it on a Proton (the largest and most expensive booster Russia owns) have been abandoned due to cost, and a stripped-down probe is being fitted to go on a smaller rocket.

Russia's international partners have expressed some skepticism about the never-before-flown collection of upper stages that will be used, but overall, the project looks feasible.

However, the change in booster rocket is having an impact on the flight hardware. The radio telescope was to use a standard deep-space bus module for its power, communications, propulsion, and control, with a 33-foot (10 meter), 1.5-ton dish antenna on top.

But at the Lavochkin Bureau in Moscow, where all Russian deep-space probes have been built, a smaller off-the-shelf bus is being modified for the mission. Details are still unclear, but now that the funding has been set, the project can finally get going. **— JAMES OBERG**

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IMAGINOVA

SH AT-SIGHTED? Cost overruns of 28 percent may force NASA to scale back, or even cancel, the James Webb Space Telescope, due for launch in 2011. Instrument changes and new accounting methods have contributed to the expense.

Smallest exoplanet yet

The smallest and most earthlike extrasolar planet yet found has been identified by astronomers. Weighing 6 to 9 Earth masses, the planet orbits a dim, reddish star that is know to hav two other planets. But this new "exo-Earth" doesn't resemble the real one very closely.

While examining two Jupiter-size planets orbiting Gliese 876M the team noticed a wobble that could not be accounted for. Precise Doppler measurements revealed an inne planet oob tiig the M dwarf star, which has about one-third of the Sun's mass.

"Now, for the first time, we have evidence for a rocky planet around a normal star," says team leader Geoffrey Marcy (University of California, Berkeley). Little is known about the exoplanet, such as its chemical composition or terrain, but it is more massive than our home planet by 6 to 9 times. The smallest previously known exoplanets have about 15 Earth masses.

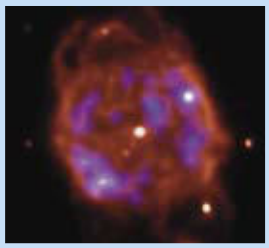
he new planet's orbit around Gliese 876 takes only 1.9 days, at a distance of about 2 million miles (3.2 million kilometers). Earth orbits about 93 million miles (150 million km) from the Sun.

The exoplanet is also much hotter than Earth: 400° to 750° Fahrenheit (470 to 670 Kelvin). Says team member Paul Butler (Carnegie Institution of Washington), "This thing is like the inner planets of this solar system — a nickel-iron rock, a terrestrial planet."

Jack Lissauer (NASA Ames) sOys the object won't hold the title of "most earthlike" for long. Scheduled for launch in 2007, NASA's Kepler mission is designed t N find Earth-size exoplanets. **— JEREMY McGOVERN**

NATIONAL SCIENCE FOUNDATION, T. SCHINDLER

HOT SPOT. An artist's view shows the newly discovered planet as a hot, rocky, geologically active world bathed in the ruddy light of its star, the red dwarf Gliese 876.



CXC/RIT

HOT SHELL. Gas heated in collisions surrounds planetary nebula NGC 40.

Hot shell envelops dying star

The Chandra X-ray Observatory has found a superhot gas shell around the planetary nebula NGC 40.

"Planetary nebulae give us a look at the Sun's future," says Joel Kastner (Rochester Institute of Technology), one of two astronomers who made the discovery.

Their work shows gas recently ejected from the star slammed into previously thrown-off gas at high speed, heating it greatly and causing it to emit X rays. **— J. M.**

GALEX sees dwarf star superflare

At 2 P.M. Pacific time April 24, 2004, NAtA's Galaxy Evo - ution Explorer (GALEX), an ultr - violet (UV) space telescope, was studying galaxies in Virgo when a faint star in its fierd o view abruptly brightened by thou sands of times.

"It was really like 20,000 times," says tea member Barry Welsh (University of California, Berkeley).

"In the far ultraviolet, the flare saturated the detector at 9th magnitude. We're not exactly ure how bright it got," he says.

The flaring star is G 3685A, a red dwarf 30 percent the Sun's size and about half as hot. Such stars make up 75 percent of the galaxy.

NASA/JPL/CALTECH

REALLY BIG FLARE. A red dwarf star brightened by more than 10,000 times.

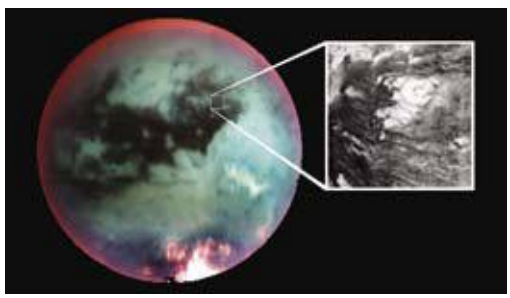
ALEX s es stars flare every 2 months or so, but most brighten only 100 times. The superflare was mor than 100 times brighter, and a million times more energetic, than a solar flare. **— F. R.**

Cassini spots icy volcano on Titan

Scientists studying infrared images of Titan believe they have found a volcano on the saturnian moon's surface. If that's what it is, it could be a source of the methane in the moon's atmosphere.

Before Cassini, scientists thought the methane came from a hydrocarbon ocean. But Cassini showed no such large, liquid body exists on Titan.

"Interpreting this feature as a cryovolcano gives an alternative explanation," says Cassini team member Christophe Sotin. The "lava" would be a mixture of methane and water-ice. The results appear in the June 9, 2005, issue of *Nature*. **— ROBERT BURNHAM**



NASA/JPL/UNIVERSITY OF ARIZONA

ICE MOUNTAIN. A false-color image of Saturn's moon Titan shows what could be a volcano (inset)u It may be a source of methane in Titan's atmosphere.

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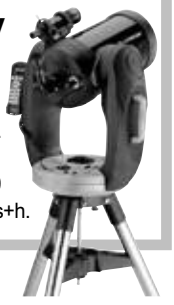

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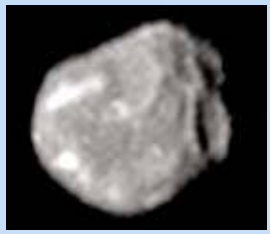
NASA/JPL/ASU IMAGE 20050524A

Ridges in Meridiani

GEO-PUZZLE. Meridiani Planum drew scientists' attention as a rover site because it is rich in hematite. This part of Meridiani lies northeast of Opportunity's landing site. It shows a generally dusty surface (cool tints) in the southern part and rockier areas (warm colors) to the north. This false-color THEMIS image from Mars Odyssey spans 16 miles (26 km).



NASA/JPL

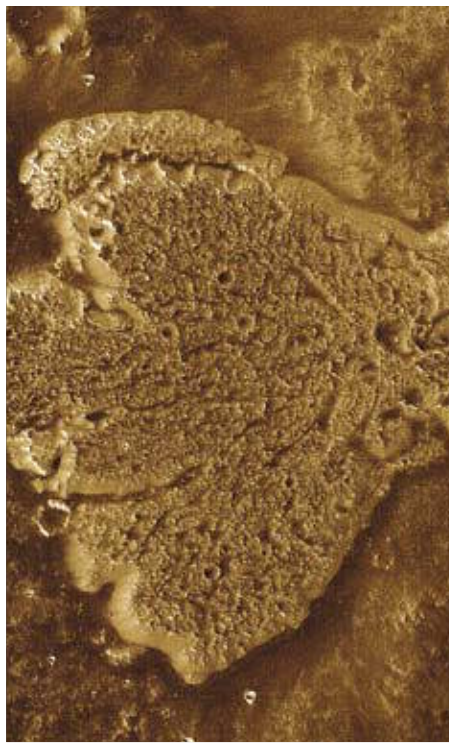
ROCK PILE. Amalthea is porous and less dense than frozen water.

Rubble-pile moon: Amalthea

Jupiter's inner moon Amalthea is less dense than water, say scientists. This suggests the body is a heap of rubble and may also contain ice.

The team, led by John Anderson (Jet Propulsion Laboratory), calculates the moon's density as 0.86 (water = 1.0). Its porosity is 30 to 55 percent, and it is likely a rock-ice mixture.

But where Amalthea now orbits was much too hot for ice to exist when Jupiter formed, so the moon must have been born elsewhere. **— R. B.**



NASA/JPL/MSSS IMAGE S05-00063

ROCKY FLOW. Daedalia Planum is a broad volcanic plain lying south of the Tharsis volcanoes on Mars. This lava flow is one of Daedalia's many. The Mars Global Surveyor spacecraft took this photo using the MOC imager. The scene is about 1.9 miles (3 km) wide and is sunlit from the upper left.

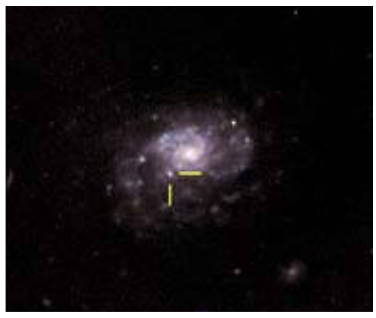
Skewed supernovae spawn GRBs?

A team of astronomers suggests an asymmetrical supernova that beamed a gamma-ray burst (GRB) away from Earth may connect type Ic supernovae to the mysterious GRBs.

Paolo Mazzali (National Institute of Astrophysics, Italy) and colleagues found that SN 2003jd, a type Ic supernova, had an asymmetrical blast like that predicted by one theoretical model for GRBs. SN 2003jd lies 260 million light-years away.

"This is the first time researchers found a supernova that might be a GRB, rather than a GRB that might be a supernova," says Brian Schmidt (Australian National University).

The star's asymmetrical detonation showed up in spectra captured by the Subaru and Keck telescopes. Says Schmidt, "It shows that the process which ripped apart the supernova is very similar to that which blows apart GRBs." **— ROBERT ADLER**



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HYPERNOVA. Supernova 2003jd blew up asymmetrically, the first jet-like explosion viewed off-axis.

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Digital images or enhanced images (including scanned photographs or slides) can be submitted online at www.astronomy.com/contest. Digital images also can be sent on a CD or Zip disk. For photographs or slides, send a transparency (mounted or unmounted), 35mm or larger, or any glossy print. Mail submissions to: ***Astronomy*/Canon Photo Contest**, PO Box 1612, Waukesha, WI 53187-1612. • The image must feature an astronomical subject and be taken by the contestant. • One entry per contestant. • Be sure to include (a) a description of the subject featured, (b) the name and address of the photographer, (c) a brief description of the photographic techniques applied. Please note if and how the photo was enhanced in any way. • **All entries must be submitted/postmarked by August 15, 2005.** • Entered photos become the property of ***Astronomy***. If ***Astronomy*** selects non-winning photos for publication, we will pay submitters at normal rates. • Judging will be conducted by the ***Astronomy*** staff. • Kalmbach Publishing Co. employees and their families are not eligible to enter this contest.

Contest winner will be announced in the November issue.

Astronomy magazine

FINAL FRONTIER. Nearly 30 years after launching Voyager 1, scientists have confirmed the spacecraft has crossed the Sun's electromagnetic termination shock and is now in the heliosheath, 8.7 billion miles (14 billion km) from Earth.

Supernova factory annex

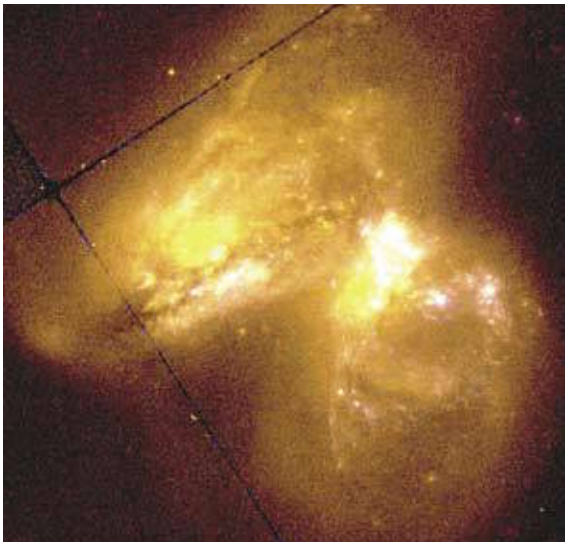
A second supernova-producing star cluster has been found in galaxy Arp 299, say astronomers. Sometime in the past 10 million years, Arp 299 underwent a furious burst of star formation. Astronomers first used the term "starburst" in connection with this object, which is really a pair of colliding galaxies (IC 694 and NGC 3690).

Massive stars formed in this latest round should be ending their lives as supernovae now. Five supernovae have popped off in the galaxy's outskirts since 1990 — including this year's SN 2005U.

In 2003, a team led by James Ulvestad (National Radio Astronomy Observatory) identified four compact radio sources it characterized as young supernovae — all within a span of 330 light-years in Arp 299's eastern nucleus. The researchers dubbed the region a supernova factory.

Now, they say, the western nucleus also contains a cluster of supernovae. The team combined observations using the Green Bank Telescope in West Virginia and the Earth-spanning Very Long Baseline Array (VLBA). With the improved sensitivity, the astronomers located four new compact radio sources in the western nucleus they believe to be young supernova remnants. The sources all lie within a region just 130 light-years across.

"The discovery of young supernovae in the western nucleus confirms it underwent its burst of star formation at about the same time as the eastern nucleus, despite being separated by tens of thousands of light-years," says Ulvestad. This is consistent with models of large-scale galaxy mergers, which show starbursts can occur almost simultaneously over very large distances. **— F. R.**



NASA/STScI

INDUSTRIAL STAR-MAKING. Many young radio-visible supernova remnants in Arp 299's eastern (left) and western nuclei hint at large, embedded star clusters.

IIU BREMEN, S. ROSSWOG

MESSY EATER. A neutron star merges with a black hole in a computer model.

Black-hole breakfast

What happens when a neutron star approaches a black hole? In Newtonian physics, the neutron star gets torn apart into an accretion disk around the black hole.

But, says a team of scientists, with relativistic physics, the star disappears cleanly without forming a disk.

M. Coleman Miller (University of Maryland), lead author of the paper giving the new results, says once a neutron star ventures closer than 3 times the radius of a non-spinning black hole, it vanishes into the black hole in a millisecond. **— R. A.**

How to see comets around other stars

If other stars have comets, we should be able to see them directly, says UCLA astronomer Michael Jura. All we need to do, he says, is use the same observatories that promise to reveal Earth-size extrasolar planets.

The goal of planet-hunters is to discover an Earth-size planet circling a Sun-like star. To find this, astronomers have proposed space observatories like the Terrestrial Planet Finder and Darwin.

These should see more than just Earth's twin, says Jura. "Any system able to obtain direct images of an analog to the Earth also will be able to detect bright comets."

MICHAEL STECKER

ALIEN COMETS. We should detect other stars' comets if they are as bright as 1997's Hale-Bopp.

Comets are much smaller than Earth, but they sprout gas and dust tails when they near the Sun.

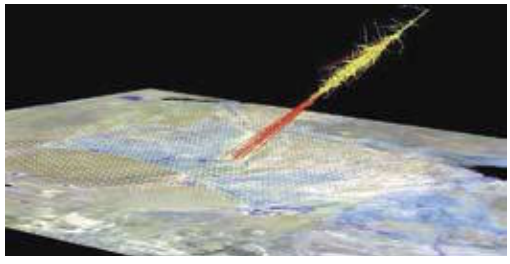
The best stars for extrasolar comet-hunters are those somewhat brighter than the Sun. **— KEN CROSWELL**

Cosmic rays radiate radio waves

Astrophysicists using a radio-antenna array have detected radio flashes associated with ultrahigh-energy cosmic rays (UHECRs).

They are the brightest and fastest radio flashes ever seen in the sky, and they mark the first time radio flashes from UHECRs have been imaged.

The array detected radio pulses that coincided with the direction of particles generated in Earth's atmosphere by the arrival of cosmic rays. Writing in *Nature* (May 19, 2005), the team says, "The close association between radio flashes and cosmic ray air showers in direction and time shows that the radio emission is directly associated with the shower itself." **— L. K.**



COSMUS, UNIVERSITY OF CHICAGO

PARTICLE RAIN. A simulation of an ultrahigh-energy cosmic-ray air shower shows red muons, yellow photons, and purple electrons and positrons.

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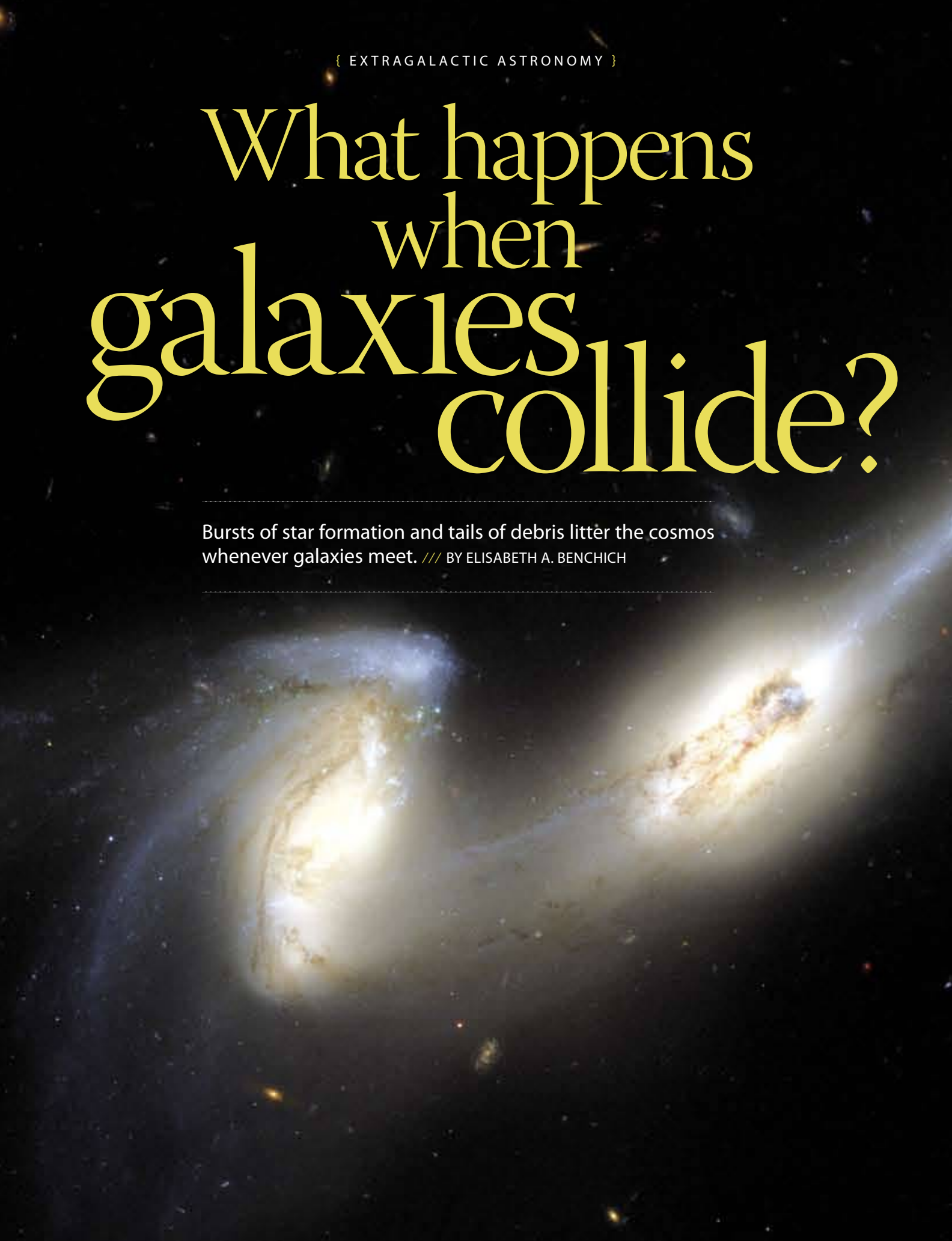
What happens when galaxies collide?

Bursts of star formation and tails of debris litter the cosmos whenever galaxies meet. /// BY ELISABETH A. BENCHICH



For decades, astronomers who pointed their telescopes toward the peculiar galaxy IC 1182 in the Hercules Cluster of galaxies thought they were seeing a single — but strange — galaxy.

With a large, not-quite-symmetric nucleus and a bright plume of material emanating from its central region, the "galaxy" didn't quite fit. Within the past few years, however, a team of European astronomers has helped clear up the confusion: IC 1182 is not just one, but two galaxies in the process of merging.

The team, led by Mariano Moles of the Andalusian Astrophysics Institute in Granada, Spain, claims it can distinguish two separate, spinning disks in the mass of material that constitutes IC 1182. These disks represent the remains of the merging progenitor spiral galaxies.

The two galaxies can't be differentiated visually — the unification is in its final stages, and the system simply looks like an asymmetric blob. Nevertheless, spectroscopic observations taken at several European observatories in 1999 and 2000 show the object's ionized gas still resembles two spinning disks.

One of the progenitor galaxies seems to have been a spiral with older stars and tightly wound arms, while the other probably was a looser spiral that contributed lots of gas to the system. "It took us some time to realize that it was a double system and to understand what is going on in IC 1182," says Moles. "The excitement was really to find an explanation that worked well for the observed data. Then, the fact of catching a system in such a particular moment of its evolution was very nice."

The astronomers also discovered a new tidal tail associated with IC 1182. This unique member of the Hercules Cluster already boasts one obvious tidal tail — a string of material pulled away from the galaxy by the gravitational influence of a neighbor. According to Moles, "[The tail] could have been due to a close encounter with some other galaxy, but not necessarily to a merging process."

But tidal tails of *merging* galaxies usually come in pairs. Sure enough, Moles and his team found a second, fainter tail. The tails have compact knots of material, some of which were seen for the first time in this study, that could evolve into separate dwarf galaxies.

As a general rule, galaxies evolve by merging to form larger galaxies, not by changing internally. This is the reason astronomers study mergers so intently. It gives them a window on the key evolutionary force governing the universe's basic building blocks — and a look at the ultimate fate of the Milky Way itself.

Galaxy-size collisions

Massachusetts Institute of Technology astronomer Alar Toomre has ordered a virtual sequence of merging galaxy pairs in an effort to clarify galaxy evolution. As astronomers Seppo Laine of the Spitzer Science Center in Pasadena, California; John Hibbard of the National Radio Astronomy Observatory in Charlottesville, Virginia; and Christopher Mihos of Case Western Reserve University in Cleveland, have written: "The Toomre sequence is useful in the sense that it represents a distribution of galaxies at different dynamical phases along the path to a merger. Understanding the evolution of merging galaxies is analogous to an alien understanding human development. If he had snapshots of a baby, a child, a teenager, an adult, and an elderly person, he could reach conclusions about human aging, with the understanding that one person does not evolve into another, but the overall evolution follows a trend."

Two beautiful examples of merging galaxies, the "Antennae" (NGC 4038/9) and the "Mice" (NGC 4676), were named after the shapes they resemble. Their exquisite forms — with enormous, arching tails and dazzling plumes of material — arose in part because the two contributing galaxies have roughly the same mass and, therefore, contribute more or less equally to the fireworks display. But this is certainly not a requirement for a galaxy merger. In fact, any type of galaxy can undergo a merger. As astronomer Daniel Christlein of Yale University and the University of Chile points out:

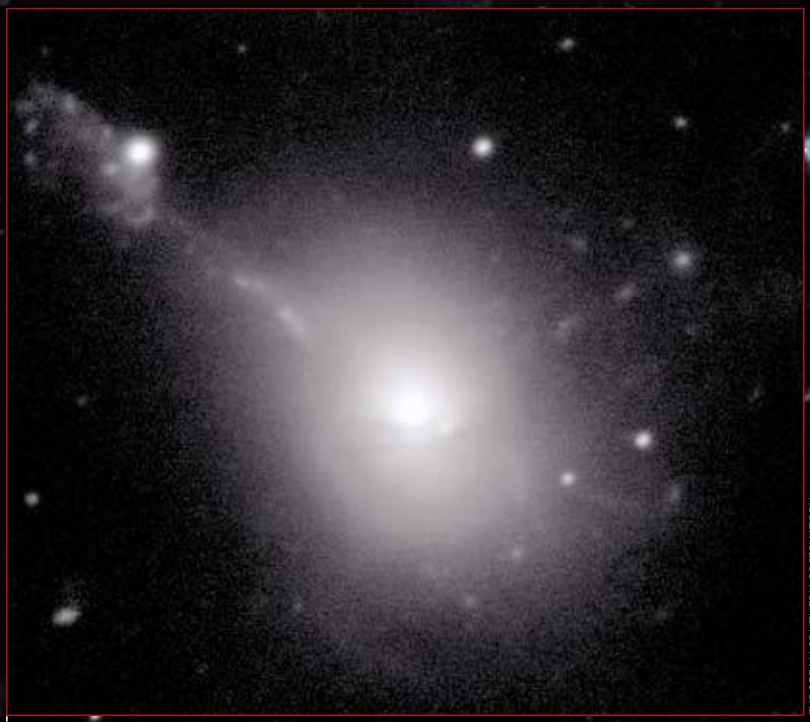
LONG TIDAL TAILS STREAM from the Mice (NGC 4676), a pair of interacting galaxies in the rich Coma Cluster. The two apparently sideswiped each other some 150 million years ago and now are heading back for a second, closer encounter.

NASA, ESA, AND THE ACS SCIENCE TEAM

NUMEROUS YOUNG STAR CLUSTERS pepper the spiral arms and debris tail of the Tadpole Galaxy (UGC 10214), whose odd form stems from an intruder galaxy (partially hidden by the Tadpole's disk). The two most prominent clumps in the tail likely will become orbiting dwarf galaxies.

EUROPEAN SOUTHERN OBSERVATORY

A RECENT COLLISION SPARKED intense fireworks in the Antennae galaxies (NGC 4038/9). Shock waves triggered by the crash created a burst of star formation — the massive new star clusters appear blue because they contain many hot, young stars.



EUROPEAN SOUTHERN OBSERVATORY

PLUMES OF STARS AND GAS erupt from IC 1182 in the Hercules Galaxy Cluster. This peculiar galaxy actually consists of two spirals in the final stages of merging — spectra reveal the remnants as two spinning disks of ionized gas.

"Minor mergers, those between a large and a small galaxy, may well be a normal part of galaxy life."

A galaxy merger requires only two conditions: The galaxies must be close enough and travel at a slow enough relative speed to be captured by their mutual gravity. Galaxies that lie too far apart don't experience enough gravitational attraction to bring them together, and galaxies that pass too quickly do not lose enough orbital energy to become bound. Rather than merge, these galaxies simply interact with each other, stripping stars and heating both systems.

Galaxies in groups and clusters are more likely to interact or merge than isolated galaxies. "If you want to understand galaxy evolution, you have to understand groups," says Christlein. "Groups happen to be the environment where you would expect these kinds of interactions to be most efficient — you have a fair number of galaxies around, but they are moving slowly enough that they have time to start the gravitational tug-and-pull."

Galaxy mergers also should become less common as the universe gets older. After all, as Christlein says, "If the expansion of the universe continues, or even accelerates, the cosmos will get increasingly rarefied, and interactions between galaxies not already in groups or clusters will become less and less likely."

Anatomy of a merger

When a large galaxy cannibalizes a much smaller one, the superior galaxy's strong tidal forces usually draw the smaller galaxy into a long arc as it is absorbed. The larger galaxy, however, suffers minimal effects.

Collisions between galaxies of comparable size, such as the Antennae, produce much more fanfare, as their equal gravities struggle against each other. Gravity can fling portions of the galaxies into space, creating enormous tidal tails. Mergers often set off starbursts as gas clouds mix and create millions of new stars.

Elisabeth A. Benchich *is a science writer living in Charlotte, North Carolina.*

The fuel for starbursts is hydrogen gas. Hydrogen in isolated spirals typically spreads throughout the galaxy's disk. In a merging spiral, however, the gravitational field can change significantly. Astronomer Daisuke Iono of the University of Massachusetts and the Harvard-Smithsonian Center for Astrophysics studies gas flows in merging galaxies. "Gas in the inner disk responds to the change in gravitational potential, loses energy and angular momentum, and flows toward the central regions of the galaxy," he says. "Numerical simulations predict radial gas inflow in the early stages, when the two galaxies have just collided for the first time, as well as during the final coalescence."

In their recent study, Iono and his colleagues found the flow occurs suddenly, although the pace slows down

"Minor mergers, those between a large and a small galaxy, may well be a normal part of galaxy life." — *Daniel Christlein*

when more than half the gas reaches the center. Once there, the gas forms a dense ring around the nucleus and can trigger the massive star formation astronomers observe. It can even provide fuel for the supermassive black hole lurking in the galaxy's center, creating the intense activity observed in active galaxies.

It's a different story in the disk's outer reaches, however. "The loosely bound gas in the outer disk is mostly ejected out of the disk into the tidal tails," says Iono.

Ironically, stellar collisions rarely occur during a galaxy merger. To many people, it seems nearly unfathomable: How could two galaxies, each boasting hundreds of billions of stars, combine into one object without a single pair of stars hitting each other?

It turns out galaxies are mostly empty space; the stars within a galaxy are spaced proportionally much farther apart than galaxies are to one another. If the solar neighborhood were as filled with stars as the Local Group is with galaxies, we'd see a few dozen stars blazing inside the orbit of Pluto.

A galactic mess

What's left after a galaxy collision depends entirely on the original properties of the participating galaxies. A large galaxy that has eaten a smaller one may show only traces of the event, such as a shell of material around its center — the victim ends up being absorbed into obscurity. Comparable-size galaxies, though, end up looking vastly different. Sometimes, the misshapen results look nothing like normal galaxies.

Astronomers classify galaxies that do not fit into any morphological category as "peculiar galaxies." We now know that almost all of these galaxies are not members of a new category, but rather, they are being affected by galaxy interactions or mergers. As astronomer Gerard de Vaucouleurs once commented, "After a collision, a car is a wreck, not a new kind of car."

Long after the fireworks die down, however, two merging galaxies can give birth to a new type of galaxy. When two spirals merge, the stars, gas, and dust of each mix together as the nuclei swirl around each other. The two flat disks cannot retain their shapes amid the disturbing gravitational forces, and the two form one large ellipsoid. So two disk galaxies can combine to form an elliptical galaxy. The emerging consensus among astronomers is most, if not all, elliptical galaxies formed through such collisions.

Merger movies

Unfortunately, no one has witnessed a galaxy collision from start to finish — it takes too long. Astronomers would have to wait many millions, or even billions, of years to see a merger through to completion. The pictures we see of mergers in progress are simply snapshots of a slow, swirling dance.

So how can astronomers reconstruct the history and plot the outcome of these mergers? They model the crash using

NASA, ESA, AND THE ACS SCIENCE TEAM

THE ANDROMEDA GALAXY (M31) is destined to collide and merge with our Milky Way several billion years from now. The beautiful spiral forms of both Andromeda and our own galaxy will be destroyed by the complex interaction.

E. PENG (JHU), H. FORD (JHU/STScI), K. FREEMAN (ANU), R. WHITE (STScI), NOAO/AURA/NSF

A BLUE ARC OF STARS in the galaxy Centaurus A (NGC 5128) is the remains of a dwarf galaxy it cannibalized a few hundred million years ago. The main galaxy's tidal forces created a burst of star formation in the infalling galaxy. The arc lies to the upper right of Centaurus A's dusty disk.

computers. Supplied with the physical laws that govern interacting galaxies, computer models help astronomers understand the mechanics of these complicated systems, and in some cases, help them infer the history and predict the future of specific systems.

Joshua Barnes of the Institute for Astronomy in Hawaii spends a lot of time constructing and running models of merging galaxies. "Some experiments take only minutes to set up — I just change a few parameters and start the calculation," he says. "Others take much longer, where we're still fiddling around with things like the initial orbit and disk geometry." Once the initial conditions are set, the computer calculates the motions of the gas or stars in the galaxy.

In his latest effort, Barnes studied the Mice. Unlike traditional models, which use the physics of local gas density to determine star formation in a merger, this new model uses shock waves. The results show that shocks more accurately predict the large-scale star formation astronomers observe in the Mice. In such a complex scenario, though, there isn't one answer. Both processes likely play important roles.

"I suspect that neither shocks nor density alone can fully account for star formation [in merging galaxies]," Barnes says. "One problem is that the computer models don't have enough resolution to capture the structure of star-forming regions, so any prescription we can implement in a computer code is going to be approximate."

Fate of the Milky Way

When we think of merging galaxies, it's tempting to think solely in terms of other galaxies — but the Milky Way has had its share of action, too. In recent years, astronomers have found evidence that shows we have been involved in anywhere from five to 11 minor mergers. The emphasis here is on the word "minor." These events were not the structure-altering fireworks of two comparable galaxies, but the relatively quiet consumption of dwarf galaxies.

The evidence is in the form of stars and globular clusters spread throughout the galaxy's halo. A recent study led by Dougal Mackey of the University of Cambridge, England, found these objects tend to fall into one of two distinct categories: young and old halo objects.

Old halo objects probably formed with the Milky Way itself. However, young halo objects could have been imported when the Milky Way absorbed their parent dwarf galaxies. The numbers and positions of these objects can, therefore, help astronomers discover our galaxy's merger history.

One such galaxy, called the Sagittarius dwarf spheroidal galaxy, is still in the late stages of merging with our galaxy. Trails of stars and clusters encircling the Milky Way mark the path of the dwarf's captured orbit. Some of these stars and clusters may be close to the solar neighborhood, according to Steven Majeweski of the University of Virginia. The center portions of the small galaxy, though, which have not been fully disrupted, are spread out in the constellation Sagittarius, giving the object its name.

> The collision between Andromeda and the Milky Way is "quite likely to be a rather messy affair." — *Dougal Mackey*

By looking at the Milky Way's collection of globular clusters, Mackey and his colleague Gerry Gilmore estimate the Milky Way has experienced roughly seven minor mergers with galaxies like the Sagittarius dwarf. "A handful of mergers is not inconsistent with the remnants that we see," says Mackey. "In my opinion, there's no doubt more remnants are to be discovered yet, probably in the form of stellar streams like those observed from Sagittarius."

Indeed, the possible remnants of another neighboring galaxy have been discovered recently, this time in the constellation Canis Major. Astronomers debate whether the abnormally high density of stars observed in this region reflects an ongoing merger. According to Mackey, however, "it's now looking more and more like the Canis Major dwarf galaxy is a bona fide dwarf galaxy." If it is a newcomer to the Milky Way, the dwarf is torn apart much more than the Sagittarius dwarf spheroidal.

Ultimately, however, the Milky Way is in for a big change. Our galaxy and the Andromeda Galaxy (M31), the largest member of our Local Group, are hurtling toward each other at about 60 miles per second (100 km/s). At this rate, a collision seems inevitable within the next 3 to 4 billion years. Because both galaxies are enormous spirals, the merger probably will resemble that of the Mice or the Antennae.

"It's quite likely to be a rather messy affair," Mackey speculates. "The gravitational forces between the two galaxies will distort and disrupt them both, sending vast plumes of stars out into intergalactic space, never to return. The first close pass will excite tidal tails, and will also probably result in a 'bridge' of stars between the Milky Way and Andromeda.

"After the first close pass, the galaxies will move apart and then fall back together a second time, sending out more stellar streams and further distorting and disrupting each galaxy. This cycle will occur several additional times, producing ever more complex patterns of ejected stars. Eventually, the densest regions of the two galaxies will merge, surrounded by a complicated mixed halo of stars."

No one knows how this event will play out — perhaps as computer models become more sophisticated, we will learn more — but it seems likely we'll end up living in an elliptical galaxy.

It will take several billion years after the merger starts until this happens, according to Laine, Hibbard, and Mihos. Regardless of the outcome, the magnificent waltz of these two spiral giants undoubtedly will be a show that astronomers, both inside and outside the galaxy, won't want to miss.

ONLINE EXTRA To watch computer simulations of merging galaxies, log on to www.astronomy.com/toc

ROBERT GENDLER

How the universe has

Astronomy's greatest hits come when the universe throws us a curveball. So what's coming next? **Marcia Bartusiak** and **Stephen Lowe** take a look into the future.

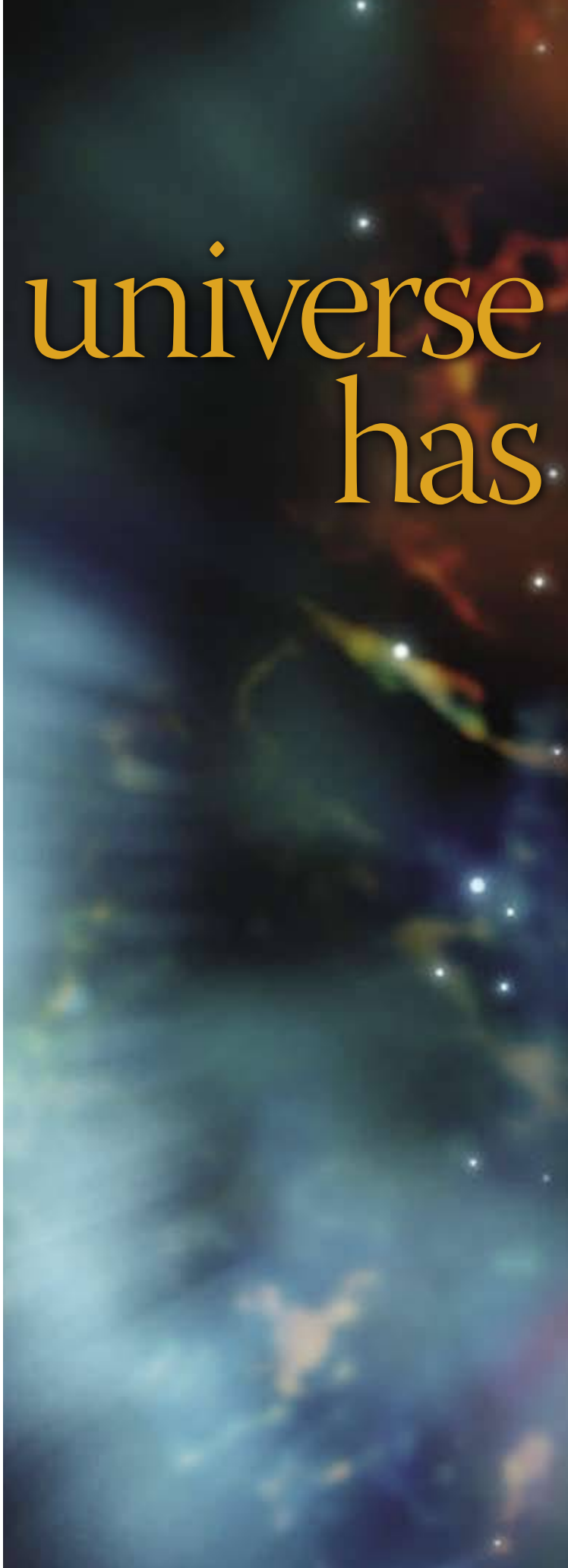
Everyone loves a surprise, be it an unexpected birthday celebration or the clever twist in a gripping mystery novel. Unlike these instances contrived by people, however, surprises in astronomy have a distinct beauty and thrill. Any new cosmic phenomenon, whatever it is, has never been experienced by any other person.

In 1572, on observing the sudden appearance of a bright star (now known to be a supernova), Danish astronomer Tycho Brahe quickly wrote a pamphlet grandly titled "On a New Star, Not Previously Seen Within the Memory of Any Age Since the Beginning of the World."

"I was so astonished at this sight," he wrote, "that I was not ashamed to doubt the trustworthiness of my own eyes." It challenged a notion, held since antiquity, that the starry heavens were unchanging.

Using an innovative spyglass in 1610, Galileo Galilei discovered the first moons circling another planet. He described the four moons of Jupiter as flying around the planet "at unequal intervals and periods with wonderful swiftness ... which [were] unknown by anyone until this day." As with Tycho's discovery, an astronomer had stumbled across something previously unknown.

Nor has this trend abated over the centuries. While closely examining streams of radio telescope data in 1967, Jocelyn Bell (later Bell Burnell), a young British graduate student, uncovered the first observational evidence that neutron stars exist. Her suspect was emitting clocklike radio pulses. British astronomer James Hey noted that "no event in radio astronomy seemed more astonishing and more nearly approaching science fiction."



BEAMS OF RADIATION from the pulsar at the core of the Crab Nebula paint the expanding supernova remnant with energy. Long predicted by theory, neutron stars, soon dubbed pulsars, still surprised astronomers when they were found.

DON DIXON

surprised us

THE ANDROMEDA GALAXY jolted astronomer V. M. Slipher (below) with an unexpectedly high velocity. Spurred by the discovery, Slipher observed many more galaxies, finding the first signs of the expanding universe.

NOAO/AURA/NSF; INSET: LOWELL OBSERVATORY ARCHIVES

In some cases, a scientific discovery, while electrifying, just culminates a line of research spanning decades or centuries. Take Edwin Hubble's discovery of other galaxies, for example. Although breathtaking and historic, his finding was not surprising. Instead, it confirmed a viewpoint long suspected, settling astronomers' lengthy debate on whether spiral nebulae were indeed other "island universes" or mere appendages to the Milky Way.

But often a new fact walks up and hits astronomers in the face. Surprise occurs more frequently when astronomers try out a new instrument that enhances their vision, as with Galileo. And sometimes, it's simply the result of sheer persistence — the dogged searching through vast surveys of celestial denizens — that turns up a rare, odd bird that no one was looking for, as with Bell's neutron star.

Little green men?

Bell's discovery is probably the quintessential astronomical surprise. A neutron star is the core left when a massive star explodes as a supernova. A compressed ball of neutrons a dozen miles wide, the stellar remnant had been predicted, but nobody was looking for it. With no nuclear burning going on to provide power, it was assumed such a tiny star would be dark and all but undetectable. But astronomers didn't realize it could beep.

A platoon of students and technicians, led by Cambridge University astronomer Anthony Hewish, had just completed a sprawling radio telescope near campus. It was scanning the sky for quickly varying radio sources, such as quasars. Bell's job was to analyze the data scrawled on the chart-recorder paper — 400 feet a week.

Reviewing the output one day, she spotted a bit of "scruff," which on further examination was a repeated beep, a hundredth of a second long, occurring every 1.3 seconds. The astronomers briefly labeled it LGM for "little green men," a jesting nod to the possibility it was an extraterrestrial communication. Continued observations, however, soon uncovered more of these "pulsars." Within a year, Cornell University theorist Thomas Gold showed how a rapidly spinning neutron star could generate the signal.

Expanding the universe

The discovery of neutron stars was swift and sweet. But a surprise can also sneak up on astronomers, its real significance emerging only after years. Around 1910, Vesto M. Slipher at Lowell Observatory set out to obtain a spectrum of the Andromeda Nebula (M31) to determine its nature. At the time, no one knew if "spiral nebulae," cloudy patches resembling whirlpools, were nearby gas clouds — solar systems in the making — or far off aggregates of stars.

It was painstaking work, requiring dozens of hours at the telescope before the nebula's faint spectral features were captured.

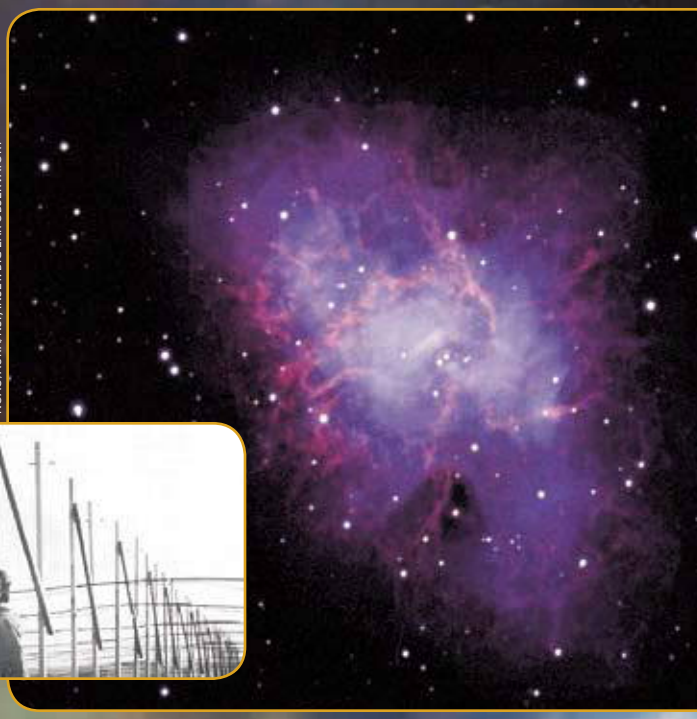
Expecting to find Andromeda moving around 12 miles (20 kilometers) per second, like other stars in our galaxy, Slipher was astonished to find it rushing toward Earth at 200 miles (300 km) per second, or 0.1 percent the speed of light. This was the greatest velocity then measured for any celestial object, and it spurred Slipher to examine other nebulae.

By 1917, Slipher's list had expanded to some 25 nebulae, nearly all of them exhibiting tremendous speeds, up to 700 miles (1,100 km) per second. Moreover, most of them were moving away from us. However, astronomers had to wait more than a decade for an explanation. In 1929, Edwin Hubble and his assistant Milton Humason were at last able to confirm that the nebulae, by then known to be galaxies, are being carried outward due to the expansion of the cosmos.

Marcia Bartusiak *is a member of* Astronomy's *editorial board. Her latest book is* Archives of the Universe. **Stephen Lowe,** *her husband, is a mathematician, software developer, and freelance writer. They live near Boston.*

WIYN/NOAO/NSF; INSET: HARVARD UNIVERSITY ARCHIVES

GLOBULAR CLUSTERS, such as M3, contains stars that are almost entirely hydrogen and helium, as first discovered by Cecilia Payne-Gaposchkin. Her finding came as a big surprise to astronomers in the 1920s.



NOAO/AURA/NSF; INSET: BIG EAR OBSERVATORY

A BIT OF SCRUFF on a chart recording from a radio telescope told Jocelyn Bell Burnell she'd found something odd in the Crab Nebula. Not "little green men" but a pulsar, the first to be found.

Seventy years later, in 1999, the expanding universe begat a new surprise, when astronomers reported the cosmic expansion is not slowing down, as everyone confidently expected. Rather, the universe is accelerating due to the action of a yet-to-be-explained "dark energy" permeating space-time. Figuring out what this is could give us a profoundly new outlook on the cosmos.

Unusual abundances?

Then there's the surprise so startling no one wants to believe it at first. Beginning in the 1860s, astronomers were identifying elements in the Sun and stars that were assumed to be present in the same proportions as on Earth. If true, elements such as iron, silicon, and carbon would fill the universe.

But around 1925, Cecilia Payne (later Payne-Gaposchkin), then a graduate student at Harvard College Observatory, drew on new theories in physics to make the first calculation of stellar abundances. She found two elements were off the charts. Her equations were telling her that hydrogen is as much as a million times more plentiful in stars than on Earth. And helium is about a thousand times more abundant than the heavier elements.

Notified of Payne's unexpected finding, Princeton astronomer Henry Norris Russell informed her that it was "clearly impossible that hydrogen should be a million times more abundant." With atomic theory so new, he was worried the simplest element was exhibiting abnormal spectral behavior. Pressured by Russell, a noted authority, Payne diluted her claim. Although she published her results, she reported the abundances for hydrogen and helium were to be "regarded as spurious ... almost certainly not real."

FINDING ANTIMATTER in large amounts would be a surprise.

Yet just 4 years later, it was Russell himself who principally convinced astronomers of hydrogen's overwhelming presence in stars. After collecting more spectral data from the Sun, he was forced to conclude that the Sun's atmosphere consists mainly of hydrogen, "with hardly more than a smell of metallic vapors in it." Ironically, he made a point of reporting that there was a "very gratifying agreement" between his findings and Payne's original numbers — all the while failing to note his role in her labeling the data as "spurious."

Such surprises are part of astronomy's lore and permeate the science's epic history. There was William Herschel's recognition of Uranus, the first planet found since the dawn of history; the discovery of the Van Allen radiation belts around Earth; gamma-ray bursts popping off like cosmic flashbulbs; the universe's bubbly large-scale structure; and an unknown dark matter spread throughout space.

Earlier this year, astronomers were stunned to see fully formed clusters of galaxies in the farthest reaches of the universe that were created just a few billion years after the Big Bang. This is far earlier than anyone guessed was possible. It is "like a kingdom popping up overnight on Earth," said University of Michigan astronomer Christopher Mullis at the time.

How to expect a surprise

With such a track record, astronomers surely will have more surprises arriving in the future. When that will happen, of course, is hard to predict — if we knew it was coming, it wouldn't be a surprise. But history teaches us that certain arenas are fertile ground for unforeseen revelations. Among these, one of the most fruitful moments occurs when a novel instrument comes on line, especially one that opens up a new field of astronomy.

Many astronomers are betting that a surprise or two will turn up as they pursue one of the last predictions of Einstein's general relativity still unconfirmed: gravitational waves, or ripples in space-time.

To catch these, physicists have erected giant sensors in which laser beams race up and down miles-long pipes to detect the slight stretching and squeezing of space-time expected if a gravitational wave passes by. Each detector acts like a surveyor's stake in a worldwide network. By triangulating their measurements, scientists might be able to trace the gravity waves back to the stunningly violent events thought to generate these cosmic quakes — for example, a star burning out and exploding as a supernova, or two neutron stars or black holes smashing into one another.

SCIENTISTS ARE BETTING general relativity will turn up a surprise or two.

Given that gravitational waves have been predicted, what might the surprises be? The most exciting possibility — the big, in-your-face surprise, the gravitational equivalent of Tycho's bright stellar flare — would be a clear signal revealing an unknown astronomical object or physical process.

Another surprise — a negative one — would be to discover that things astronomers already expect to be gravitational-wave emitters (stellar-mass collisions and detonations) don't play out exactly as we think they do. This would reveal flaws in our understanding.

Enough string

Syracuse University's Peter Saulson says another gravitational-wave source is cosmic strings, entities arising in some grand unified theories of physics. Flaws in the topology of space-time, cosmic strings can be thought of as extremely thin tubes, skinnier than an atomic particle, in which the energetic conditions of the Big Bang's primeval fireball still prevail. Such strings could be exceptionally long (spanning the width of the universe) or closed loops, and they continually vibrate at velocities approaching the speed of light, perhaps making them emit gravitational waves.

Even though such energetic objects would create sizable gravitational waves, the waves become extremely weak by the time they cross the universe to reach Earth.

The stretching and squeezing of space-time is expected to be smaller than the width of a proton. This forces gravitational-wave physicists to push their detectors to the limit, which may suppress immediate surprises.

One way to see the signal in the noise is to assume what the gravity-wave signal will be like. Just as knowledge of human speech patterns helps you make out words from a weak, far-off radio station, gravitational-wave physicists use mathematical models — templates — of gravity-wave signals. When analyzed, signals that match the models will be detected, but those that don't correspond will be written off as terrestrial or cosmic clatter.

Other gravitational-wave physicists hope to pick up weaker "unmodeled bursts" by carefully scanning for more generic signals such as persistent tones or smooth changes in pitch, or even combinations of these that occur together in a kind of brief musical score. Because astronomers don't presuppose the tune, this method may see truly unexpected gravitational-wave emissions that unveil new physics, new astronomical objects, or surprising information about known objects.

Search the familiar

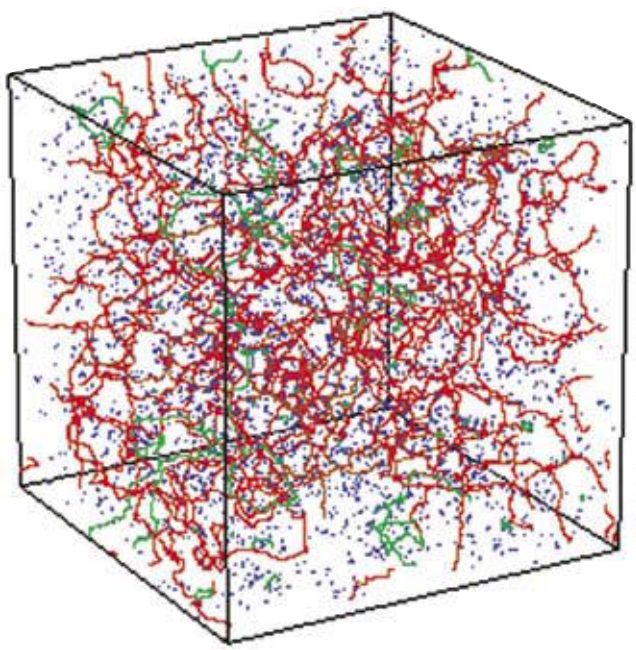
In addition to searching for novel objects, looking at collections of known objects might turn up some unexpected events. "In terms of the populations that create sources [of waves]," says MIT's Scott Hughes, "I think you have a little bit more room for a surprise." For example, gravity-wave observers expect to detect binary black holes spiraling in and merging, but what if they see a large number of such events?

"That would be an enormous surprise," says Hughes, "because I don't know where we would get them from." In other words, how could certain stars "arrange to die" so that many conveniently ended up as two black holes closely circling one another?

New capabilities in optical astronomy may lead to surprising discoveries in the search for extrasolar planets. So far, astronomers have depended on planets either being very massive or rapidly moving to pick them out. Consequently, only certain kinds of extrasolar planetary systems are revealed. None of the systems found so far closely resemble our solar system, with its rocky terrestrial planets close to the Sun and gas giants farther out.

But planet-hunters are starting to look for transits — the passage of a planet between its star and the viewer — to detect a wider range of planetary sizes. By measuring the tiny decrease in light from the star due to the planet's shadow, as well as measuring the time required for the crossing, astronomers can extract information about the planet's size and orbit.

Of course, the alignment has to be just right (we have to be in the plane of the planet's orbit) and that means looking at lots of stars to find those lucky setups.



NATIONAL TAIWAN UNIVERSITY, J. H. P. WU

QUIVERING NANOTUBES comprise string theory's universe in place of particles. If correct, the theory may kick astronomy into new paths.

LIGO

LIGO

A SHIMMY IN SPACE-TIME will tell astronomers a wave of gravitational radiation has passed by, perhaps from two merging black holes (above). Racing laser beams look for gravity waves at LIGO, the Laser Interferometer Gravitational Wave Observatory (right).

But a NASA mission called Kepler, to be launched in 2007, will monitor 100,000 stars continuously and detect the transits of planets as small as Earth. This will be the perfect opportunity to find a planetary family looking like our own.

And once we can detect such planets, will we find that our solar system is the normal arrangement for planetary systems within the Milky Way after all? That's not clear. The first planetary systems sighted in the 1990s were found to be strange: planets more massive than Jupiter circling close to their suns.

Andrea Ghez of UCLA points out that at the time, astronomers' models for the formation of stellar systems "couldn't produce any of these weird-looking planets." The models had to be revised after the discovery.

"There's a whole cottage industry now of trying to explain how you get massive planets really close to the central star," she says. Because the models are still being adjusted, Ghez adds, "I just suspect that we're in for a few more surprises once we get down to being able to detect all the kinds of planets that are within our solar system."

Seeing new colors

Help in sorting out such riddles of stellar systems may come from submillimeter radio astronomy. Submillimeter is a part of the electromagnetic spectrum that is not well-covered, says John Huchra of the Harvard-Smithsonian Center for Astrophysics. "We're just beginning to get telescopes that work reasonably well," he says. "But, unfortunately, they have to be up at 18,000 feet [5,400 meters] in high and dry conditions. My suspicion is that we're going to learn a lot of things about star formation and protoplanetary disks, because submillimeter is a region that's pretty good for tracking that kind of activity."

Turning to our own celestial backyard, exploring Mars and Saturn's moon Titan have the potential to end the most suspenseful wait of all. "A profound discovery would be life," says Woody Sullivan of the University of Washington. "The surprise would be if it were completely different, either in chemistry or in its method of storing genetic information; or if it were not based on water." And there's always the hope the search for extraterrestrial intelligence will turn up some neighbors.

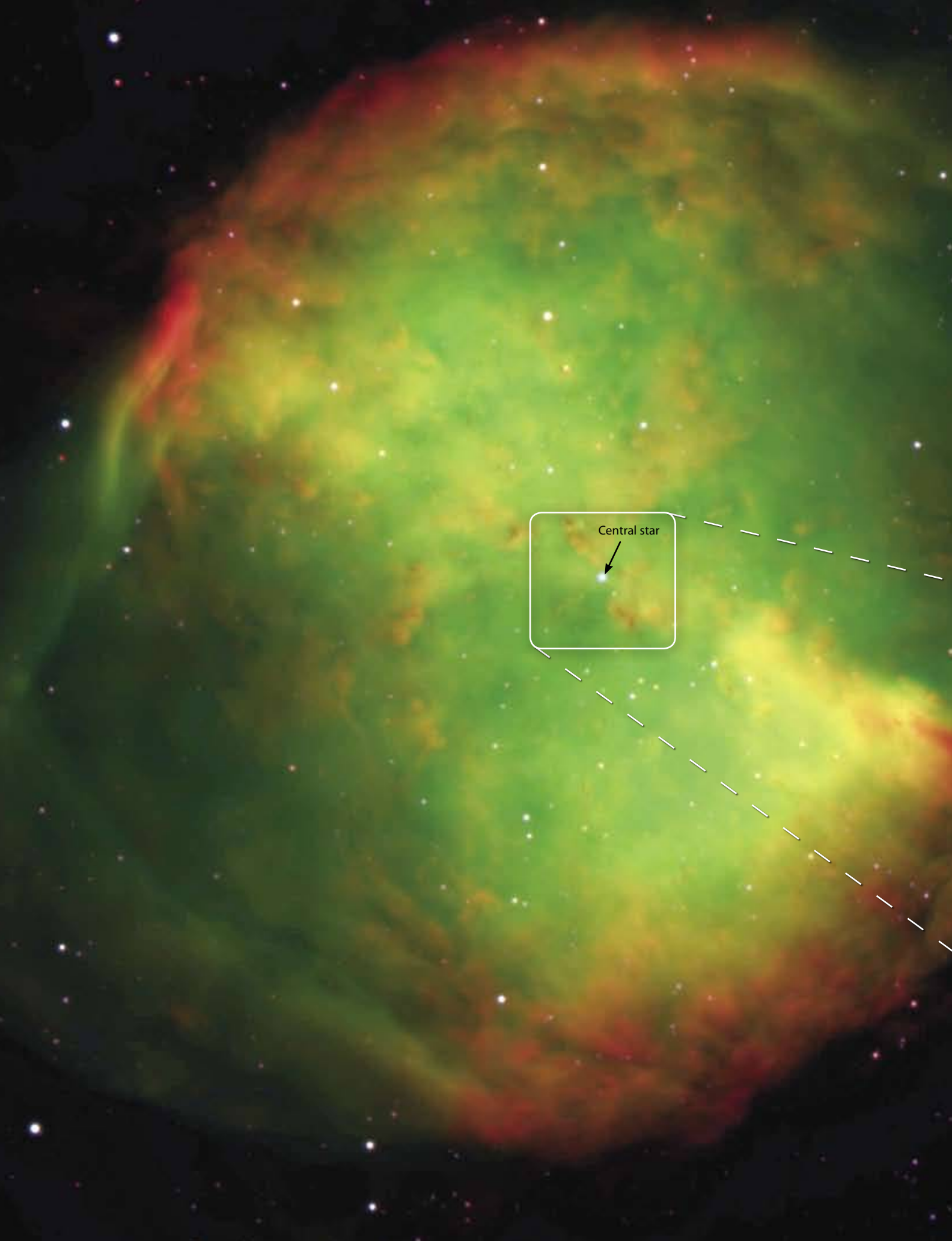
Phenomena whose causes are poorly understood are also good targets for unexpected findings. Consider the supermassive black holes lurking in the hearts of most galaxies. When first discovered, these central black holes were thought to be associated only with quasars and other active galactic nuclei, which spew out huge amounts of energy. "So the discovery that most galaxies have central black holes was a surprise," says Ghez. Then, it was a surprise to find that the size of the supermassive black hole correlated directly with the size of a spiral galaxy's central bulge. "Presumably," says Ghez, "that's one huge hint as to how galaxies form."

Astronomers are often reluctant to make predictions too off-the-beam, but John Huchra is willing to go out on a limb. He notes that, although we know antimatter exists, we've never detected a large piece of it, such as an entire antimatter star or galaxy. There's reason to believe these are not so common: to avoid emitting copious radiation from matter-antimatter annihilation, such entities would have to be isolated, even from the dusty, gaseous interstellar medium.

But an antimatter star far out in the galactic halo might be isolated enough. "So, one surprise would be the detection of a significant antimatter object," says Huchra.

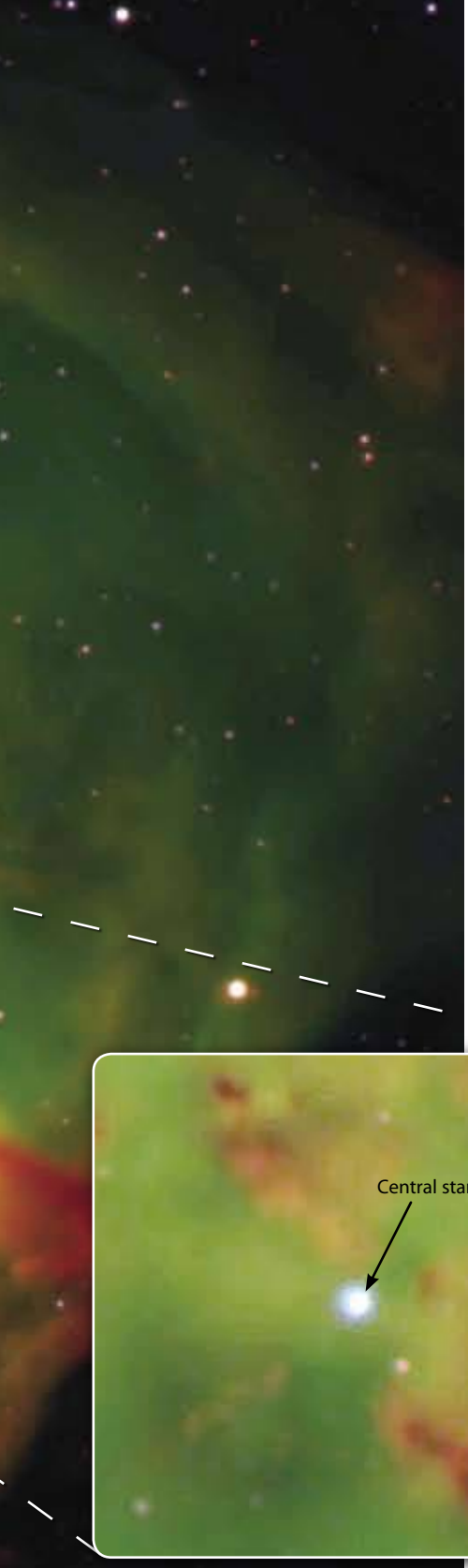
It's easy for astronomers and astrophysicists to imagine all sorts of weird things, but ultimately, only a small fraction will turn out to exist. And things they don't imagine at all will make a sudden appearance out of the blue. Surprises like that just come with the territory. A

ONLINE EXTRA For more on astronomy discoveries, see www.astronomy.com/toc


Central star

Ready, set, BOOM!

An expanding bubble enriches the galaxy and may help life begin. /// BY KEN CROSWELL



LIFE-ENRICHING ELEMENTS glow in red, yellow, and green from the ultraviolet light of the Dumbbell Nebula's central star. *Inset:* A close-up of the Dumbbell Nebula shows knots in the gas surrounding the star. Before the central star expanded to a red giant, it was a hot O7 star.

ESO

ALL YOU EAT, DRINK, AND BREATHE contains atoms forged in distant, massive stars that exploded as supernovae. But one vital element — nitrogen — entered space gently, when less massive suns cast it off in planetary nebulae.

A stunning example decorates the summer sky in the constellation Vulpecula. Although it bears an odd name, the Dumbbell Nebula (M27) resembles a beautiful Christmas ornament. Parallax data from the Hubble Space Telescope indicate it's 1,400 light-years from Earth and 2.1 light-years across along the yellow axis that runs from 10 to 4 o'clock. If the Dumbbell Nebula surrounded the Sun, it would stretch a quarter of the way to Alpha Centauri — the nearest star system to the Sun.

The Dumbbell marks the spot where an aging red giant star cast its atmosphere into space and exposed its core. The core's diameter is only 6 times that of Earth, but it's so hot — 110,000 kelvins versus the Sun's 5,800 K — that it's bright enough to see in this image.

Because of the star's high temperature, it emits ultraviolet radiation that sets the gas aglow, creating a collage of green, yellow, and red. The dominant color, green, comes from oxygen; but most of the gas is hydrogen, which contributes some of the red. Where the green and red mix, they make yellow.

Oxygen and hydrogen are vital for life, but neither arose in planetary nebulae. Instead, the oxygen came from stars that exploded, while the hydrogen emerged from the Big Bang.

Nevertheless, the quiet suns that produce planetary nebulae have contributed more than 90 percent of the universe's supply of another life-giving element, nitrogen. This element constitutes an essential part of protein and makes up 78 percent of Earth's atmosphere. With every breath, you inhale the offerings of innumerable planetary nebulae.

Thanks to the stars that produce these nebulae, nitrogen is the sixth most abundant element in the cosmos, after hydrogen, helium, oxygen, carbon, and neon.

The star that created the Dumbbell Nebula certainly did its share. The Dumbbell has 2 to 3 times the Sun's nitrogen-to-hydrogen ratio. Nitrogen, like hydrogen, glows red, accounting for some of the red color in this image. The star also created another crucial element, carbon. The Dumbbell has twice the solar carbon-to-hydrogen ratio.

The Dumbbell Nebula's progenitor star was born with several times the Sun's mass. The Sun itself is destined to swell into a red giant 7 billion years from now and then shed its atmosphere. Because of its lesser mass, though, the Sun will offer no new carbon; however, it will contribute a small amount of helium and nitrogen.

The Sun's cast-off elements will swirl around the Milky Way Galaxy. Some will enter interstellar clouds that are giving birth to new stars and planets. Calculations suggest the Sun's new nitrogen could endow roughly 100 million terrestrial planets with atmospheres like our own. Thus, even after it dies, the Sun, which now supports life on Earth, may continue to do the same for other planets.

Ken Croswell *is an astronomer in Berkeley, California, and the author of* Magnificent Universe.

Evolution

Astronomers find that comets are not the pristine relics we thought they were. /// BY S. ALAN STERN

Astronomers study comets for the promise of looking at well-preserved relics from the outer solar system's formation days. However, the original theories of comets as completely pristine samples have changed over time. Scientists now see comets as somewhat damaged goods that have sustained numerous different evolutionary processes.

In the beginning

In 1950, Fred Whipple of Harvard University determined the solid body that generates the beautiful coma and tail seen from Earth is actually a flying mountain of ice. Later that year, Jan Oort of Holland discovered comets are remnants of the formation epoch of the planets. Oort said cometary material originated among the giant planets, and it was then ejected to a far-away reservoir (located 10,000 times as far from the Sun as Earth) that now bears his name — the Oort Cloud. Together, Whipple and Oort put in place the basic paradigm for what comets are and where they originated.

The implication of Oort's idea was particularly profound, and decades of research have refined his theory. According to Oort, because comets are stored so far from the Sun, where temperatures are only a few degrees above absolute zero, they must be pristine relics of the solid material that formed the outer planets. Evidence confirmed Oort's idea: Comets are perfectly preserved relics of the planetary-formation era some 4.5 billion years ago.

Over time, planetary astronomers concluded that comets contain about as much dirt

S. Alan Stern *is a planetary scientist at the Southwest Research Institute in Boulder, Colorado.*

at the edge

COMET NUCLEI TUMBLE through space at the edge of the Sun's domain. These "damaged goods" undergo far more than astronomers thought 40 years ago. ILLUSTRATION BY LYNETTE COOK

COMET HYAKUTAKE put on a fabulous show in 1996. Because of its highly elliptical orbit, this outer comet came within 9.3 million miles of Earth. BILL AND SALLY FLETCHER

as ice. We also found that while most long-period comets do come from the Oort Cloud, short-period comets come from a closer (but nevertheless very cold) reservoir outside of, and overlapping, Pluto's orbit — the Kuiper Belt. But the essence of the theory remained unchanged — comets are "untouched" samples of the solar system's earliest days.

A shift in view

The conceptual shift away from seeing comets as pristine relics began in the 1970s. Laboratory astronomers around the world began to simulate the kinds of radiation suffered by bodies in space. In the same way experience broadens our worldview, astronomers' views of comets have also evolved.

Astronomers found that comets, although very far from the Sun, still were bathed with ultraviolet radiation that, over billions of years, can darken and color their surfaces.

Researchers also showed that high-energy cosmic rays emanating from the Sun and galactic sources penetrate cometary surfaces to depths of up to several yards, and in doing so, alter chemical bonds and even the microscopic structure of cometary surface materials. Together, ultraviolet and cosmic rays create a rind on comet surfaces.

However, these discoveries did not force astronomers to rethink their theories. They believed that as soon as a comet approached the Sun — where we could study it — the Sun's intense heat would remove the "damaged goods" of the surface layer quickly by evaporating surface ices.

About the same time, scientists realized comets could be heated internally by the decay of radioactive isotopes that are common in meteorites. Thus, deep cometary interiors could have warmed to temperatures that, in the extreme, could have evaporated ices like carbon dioxide and water, thereby causing comets to evolve internally at an early stage in their history.

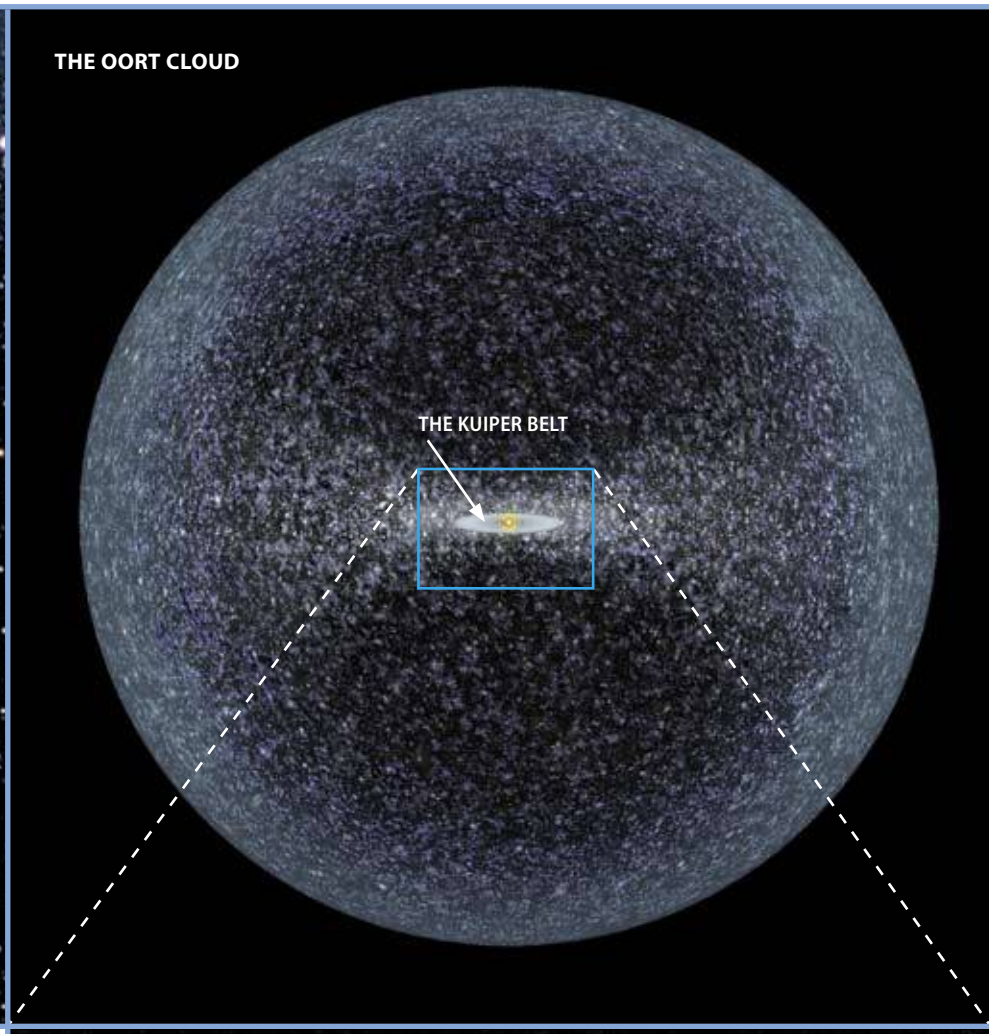
This finding further eroded comets' longstanding reputation as pristine relics of the solar system's formation. This was especially insidious because the altered interiors would appear gradually as upper layers peeled away and evaporated over time under the heat of repeated solar passages.

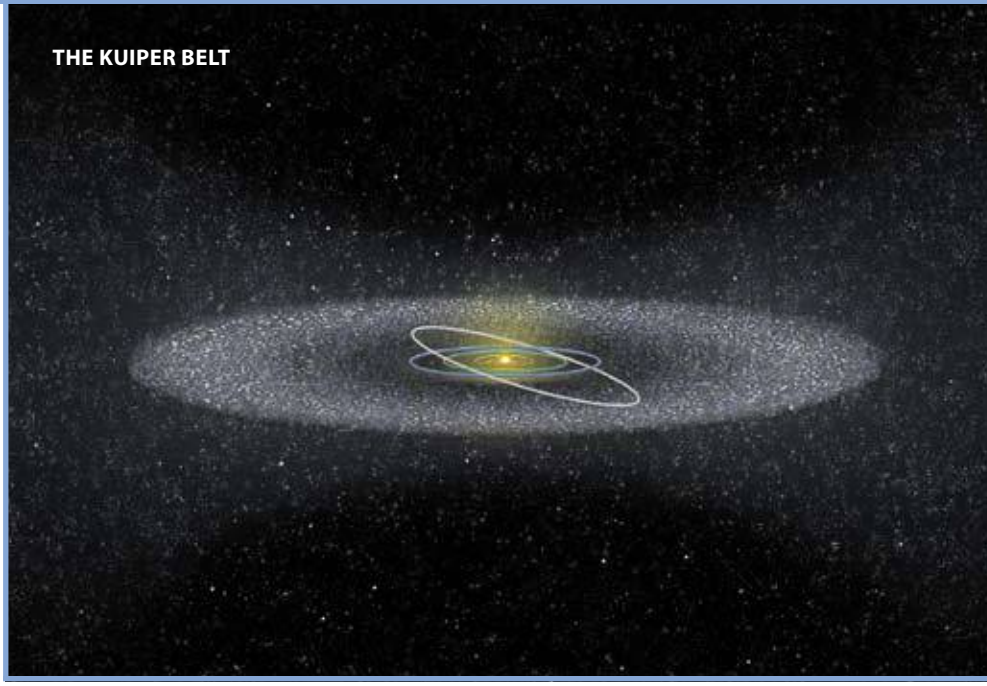
Adding complexity

By the late 1980s, I began researching comet evolution. Within weeks, I discovered that cometary surfaces suffer a kind of sand-blasting during their time far from the Sun.

The Sun's speed relative to the gas and dust in the interstellar medium (the material between the stars) is about 62,000 mph (100,000 km/h). At this speed, every collision with interstellar dust erodes the cometary surface. Model calculations show that, over time, this erosion could

ONLINE EXTRA For information on what NASA's Deep Impact comet probe found, go to www.astronomy.com/toc



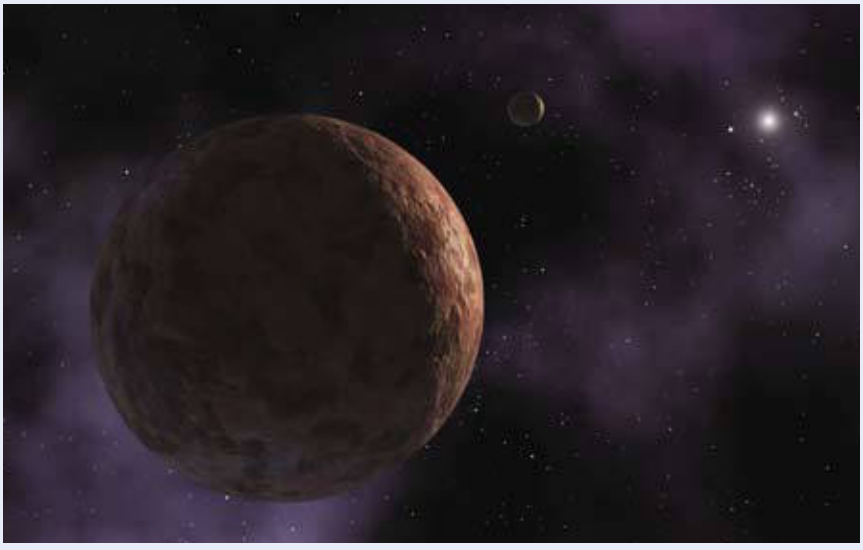


strip cometary surfaces of a layer as shallow as a few inches or as deep as a few tens of yards.

Exactly how much material would be removed is uncertain, largely because no spacecraft has ever landed on a cometary surface and revealed its density, porosity, and other physical properties. With the collision of Deep Impact, our understanding of a cometary surface should deepen. While the quantitative effect of this interstellar erosion cannot be gauged, its existence is hard to deny.

About the same time that interstellar erosion was identified, Michael Shull of the University of Colorado and I discovered faraway comets don't always remain as cold as previously thought; they experience brief heating episodes. We determined the Sun isn't the only heat source comets endure. Rare passages of very luminous stars — O and B stars in particular — can come close enough to the

HOVERING FAR FROM THE SUN — beginning at roughly 5,000 AU and extending as far as 100,000 AU — the Oort Cloud may have as many as a trillion comets. The inner ring on the image is the Kuiper Belt, which overlaps Pluto's orbit at times and contains a few billion comets. Because the Kuiper Belt occupies a much smaller volume, it has a higher comet density than the Oort Cloud. *ASTRONOMY:* ROEN KELLY



NASA/JPL-CALTECH

SEDNA, discovered in November 2003, might not have water or methane ice on its surface, as shown in this artist's representation.

PERPLEXING PLANETOID

Since its discovery November 14, 2003, the Oort Cloud planetoid Sedna continues to surprise astronomers. Scientists know it is 1,120 miles (1,800 kilometers) across — roughly 2/3 the size of Pluto — and that it is the most distant solar system object detected. And while they know Sedna has a highly elliptical, 11,500-year orbit — getting as close to the Sun as 76 AU and as far away as 1,000 AU — much about the planetoid remains a mystery.

Did Sedna form between Jupiter and Saturn, and was it then flung into the Oort Cloud by a stellar intruder? Did it form around a different star only to be sucked into our solar system? Or did Sedna, as S. Alan Stern's research shows, form right where it is now, with another star altering the planetoid's orbital eccentricity and inclination? Only future discoveries can solve this puzzle.

When Sedna's orbit was first calculated, it appeared to complete one rotation in 20 days. Because of this long rotation period, scientists expected the planetoid had a companion moon slowing its rotation. But they couldn't find a moon. Instead, astronomers saw a subtle variation in Sedna's rotation they didn't see before. After further observations and calculations, they found Sedna completes one rotation in 10 hours. It appears Sedna has a typical rotation period after all. No moon needed.

Most recently, the astronomers who discovered Sedna, led by Michael Brown of the California Institute of Technology, found it has avoided collisions because of its distance from other objects. Infrared studies from the Gemini North Telescope on Mauna Kea, Hawaii, show the planetoid has a smooth surface. These observations also show a lack of methane and water ice, meaning there may be a lot of asphalt-like "goo," caused by ultraviolet and cosmic rays, on Sedna's surface. — *Liz Kruesi*

Oort Cloud to warm it to up to 30 kelvins for thousands of years at a time.

We also estimated that, over time, a handful of supernovae had exploded close enough to the Sun (within 30 to 65 light-years) to warm the entire Oort Cloud briefly to temperatures as high as 70 K. Although these temperatures are frigid by terrestrial — and even martian or jovian — standards, they are warm enough both to sublimate some frost species in cometary surfaces (such as methane, nitrogen, and light noble gases) and to promote certain chemical reactions in the ices near the surface.

Chips off the old block

If these findings weren't enough, the clincher was discovered in the late 1990s, when groups, including my own, began to study the effects of comet collisions within both the Oort Cloud and the Kuiper Belt. Scientists found that although the Oort Cloud's cometary population is high — comprising perhaps 1 trillion comets — the Oort Cloud's volume is so large that cometary collisions are exceedingly rare.

By contrast, the Kuiper Belt, although populated by perhaps only a few billion comets, is 1,000 times more compact than the Oort Cloud. This creates a higher density of comets in the Kuiper Belt and makes for frequent collisions — on astronomical timescales. Virtually every primordial comet in the Kuiper Belt should have been destroyed by now as a result of high-speed collisions.

In addition, scientists found new comets would be created by the collision fragments of large Kuiper Belt objects (KBOs). The implication of this finding, made by multiple research groups using independent computer models, was significant: Most comets that originate in the Kuiper Belt are not likely ancient, as previously thought, but are instead "recently" created chips off of KBOs. They are created in much the same way as small asteroids, which scientists know are collisional fragments ejected from larger asteroids.

Childhood's end

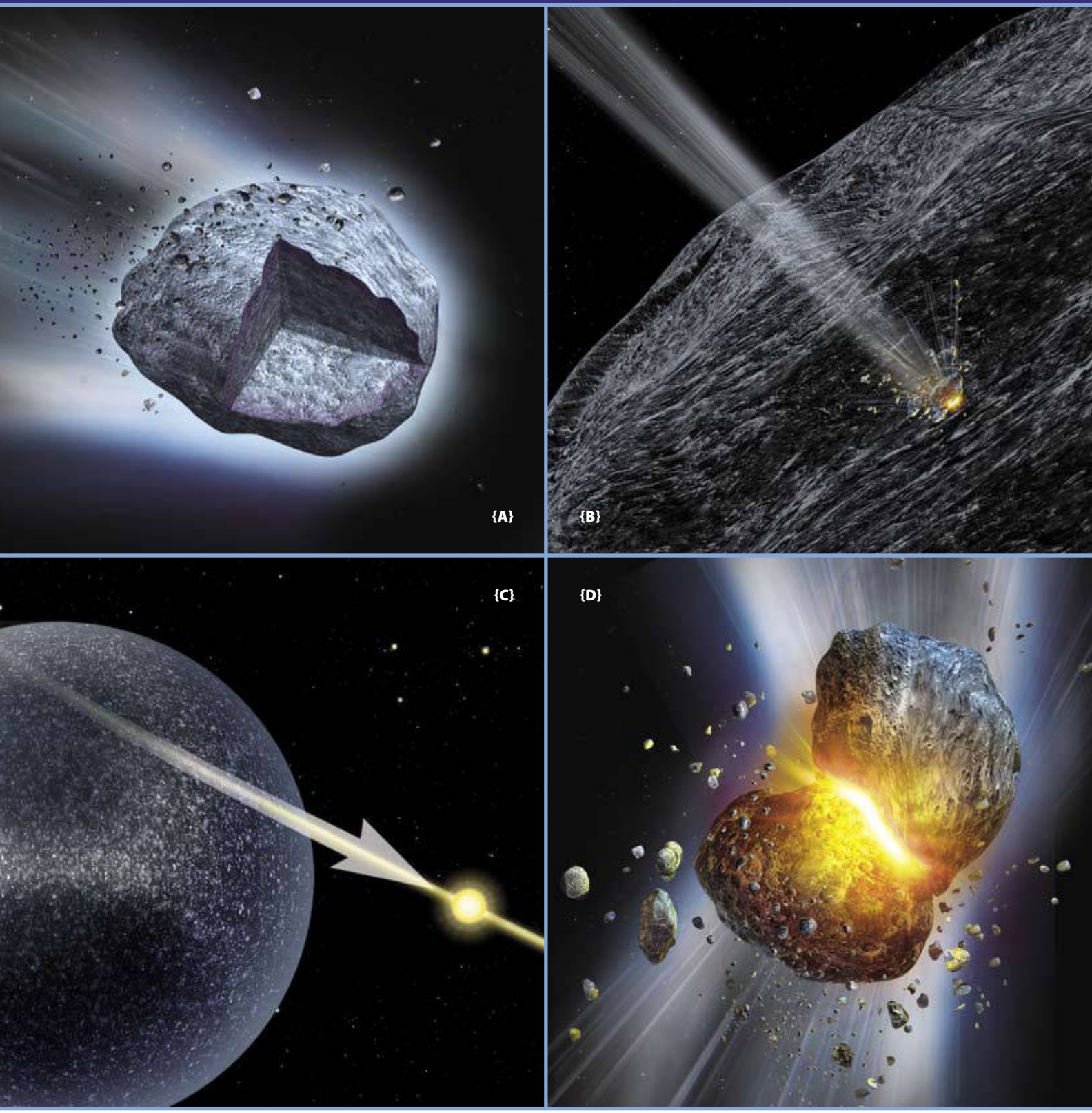
The bewildering array of cometary evolutionary effects that have been identified over the past few decades has changed our view of comets as pristine relics. We now appreciate that there are many shades of gray between wholly pristine and simply old material. Astronomers still think comets are the best-preserved samples of the stuff from which the outer solar system was made, but they are not the perfect samples they were once thought to be.

Does this lower the value of cometary studies and the need for sample-return missions from comets? Not at all!

If anything, comets have more to tell us than we once believed. We now know they hold a good, if imperfect, record of the solar system's earliest era. Comets can tell us of the system's travels through the radiation fields and dust clouds of the Milky Way, luminous star encounters, and even the effects of collisions between ancient bodies orbiting the Sun.

As we look forward to new journeys to comets, like the Rosetta cometary orbiter and lander, and — just perhaps — a cometary sample-return mission, we should expect that the story will become more and more interesting. Just like other kinds of solar system bodies — from Mars to the icy satellites of Jupiter and Saturn, and to KBOs — comets should still have surprises in store for us.

ALTERING A COMET'S MAKEUP — INSIDE AND OUT



{A} **COMETS ARE DAMAGED** as cosmic rays and ultraviolet radiation penetrate some distance into the comet nucleus, creating a rind on the surface (damaged layers are purple in this schematic diagram) and altering material at deeper levels. **{B}** **INTERSTELLAR DUST GRAINS** peel away a comet's surface (in this zoomed-in diagram) — on the order of a few inches — as a comet flies through the outer solar system over billions of years. **{C}** **STELLAR NEIGHBORS** are an outside heat source as they come close — and even enter — the Oort Cloud. **{D}** **COMET COLLISIONS** in the Kuiper Belt are more common than in the Oort Cloud. Scientists actually may be looking at "newer" comets — fragments from ancient-comet collisions — when looking at KBOs. *ASTRONOMY:* ROEN KELLY

September 05

A stunning sight awaits viewers in early September, when Venus and Jupiter have their most spectacular evening conjunction in more than 3 years.

A conjunction for the ages

Blazing beacons Venus and Jupiter appear

striking as twilight falls in early September. Scan for them low in the west-southwest 30 to 45 minutes after sunset. The sky darkens quickly at this time of year, so the two brightest planets become more prominent as the minutes pass. But make sure you have an uncluttered horizon — otherwise, the pair will be lost behind trees or buildings.

Although Jupiter shines brightly, Venus dazzles in comparison. And while Venus gleams a pure white, Jupiter shines a few shades toward pale peach. Watch how their colors deepen toward orange, and even red, as they descend through Earth's thick lower atmosphere.

The planets appear closest to each other September 1. Nevertheless, you should start looking during the last week of August to see Venus climbing away from the Sun while Jupiter slides in. Mark your calendar for September 6, when the waxing crescent Moon joins the duo to create a stunning trio. View the gathering with your naked eyes and binoculars. With this optical aid, you should see a fainter sparkle directly below Venus and to the Moon's left: the bright star Spica.

Don't miss this conjunction — the next nice one between the two brightest planets happens in February 2008.

Rusty-orange Mars now rises during mid-evening, surprising casual skywatchers because it shines almost as bright as Jupiter. Its increasing prominence results from Earth's gradual approach, which makes Mars appear both bigger and brighter. Despite its brightness, Mars can be a bit of a disappointment for newcomers getting their first telescopic view. Experienced observers see a large disk brimming with subtle details under "good seeing" — when our atmosphere steadies and details come into sharp focus. A beginner needs to train his or her brain to recognize low-contrast dark patches on the tiny dot. Only time at the eyepiece can accomplish this. Another common mistake of novices is to observe Mars as soon as it rises, when Earth's turbulent atmosphere usually erases all detail in a rushing blur. Wait until midnight for better conditions.

FRANK ZULLO

VENUS AND JUPITER passed each other during dusk in February 1999, an arrangement they'll repeat in early September.

The Moon hides in the Sun's glare at the start of September, then returns to form a lovely trio with Venus and Jupiter the evening of the 6th. Look for the gray shading on the dark side of the Moon. Astronomers call this light earthshine because the Moon is returning sunlight that has reflected off Earth.

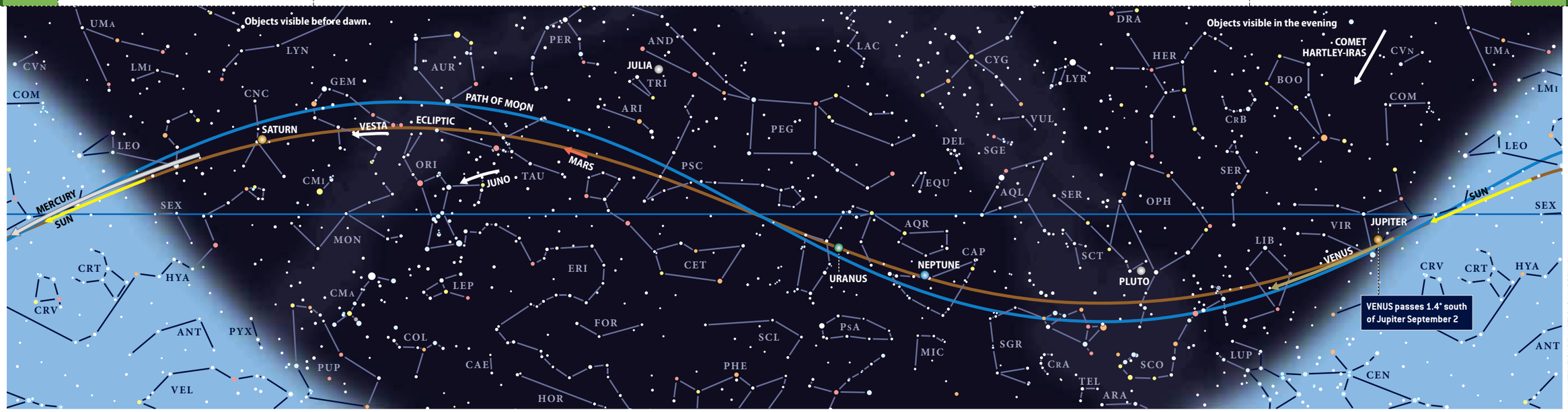
Note the Moon's path over the next several evenings. It crawls low across the south until it becomes Full the night of September 17 — the Harvest Moon. Four nights later, it joins Mars near the Pleiades cluster (M45).

Saturn, the bright yellowish "star" in the east as dawn breaks, also goes by the name of the Greek god Cronus. Across the millennia, Cronus has been confused with Chronos — father time. It doesn't help that Saturn takes 29.5 years to complete a full circuit of the background sky, providing a handy measure of time's passage. Indeed, it's a celestial anniversary of one of this column's authors, Alister Ling: "I first laid eyes on Saturn in November 1975, when it made a nice triangle with Castor and Procyon. I'll never forget the view through my new 4.5-inch scope, aimed between the trees from the sidewalk. I'm sure it will stir more memories when I see Saturn in Cancer again."

The distant gas-giant planet Uranus reaches its peak the night of August 31/September 1. At magnitude 5.7, it glows brightly enough to be spotted with the naked eye from a dark site. Find it first with binoculars next to the 4th-magnitude star Lambda (λ) Aquarii.

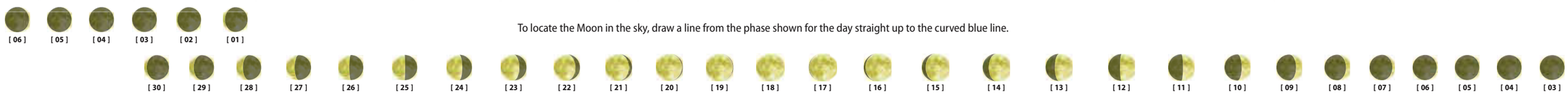
Planets this month

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.



ALL ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

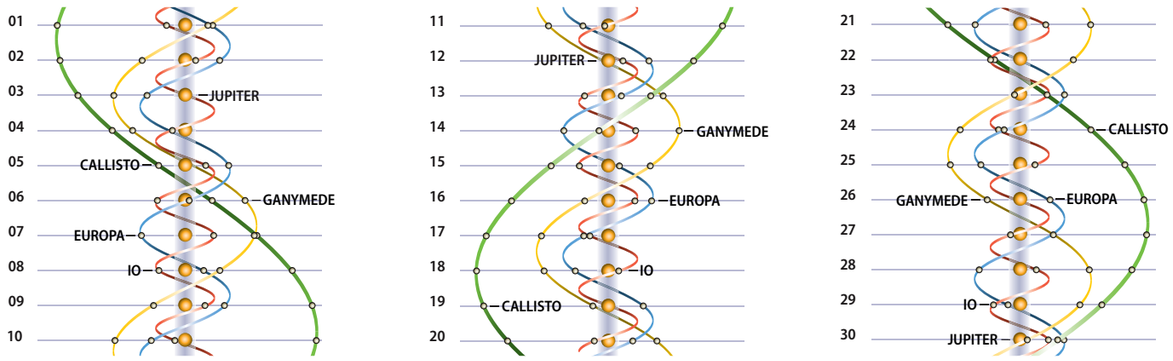
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.



PLANETS	MERCURY	MERCURY	VENUS	MARS	MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	September 1	September 30	September 15	September 1	September 30	September 15	September 15	September 15	September 15	September 15
Magnitude	–1.1	–0.9	–3.9	–1.0	–1.7	–1.7	0.4	5.7	7.9	13.9
Angular size	6.0"	4.8"	16.0"	14.1"	17.7"	31.3"	17.0"	3.7"	2.3"	0.1"
Illumination	75%	97%	70%	87%	93%	100%	100%	100%	100%	100%
Distance (AU) from Earth	1.127	1.398	1.041	0.663	0.529	6.308	9.775	19.093	29.251	30.995
Distance (AU) from Sun	0.308	0.440	0.728	1.396	1.419	5.451	9.090	20.070	30.060	31.005
Right ascension (2000.0)	9h44.0m	12h59.7m	14h04.8m	3h01.5m	3h25.8m	13h19.9m	8h39.2m	22h40.4m	21h10.8m	17h26.3m
Declination (2000.0)	14°47'	–5°54'	–13°40'	14°17'	16°24'	–7°15'	18°48'	–9°16'	–16°25'	–15°20'

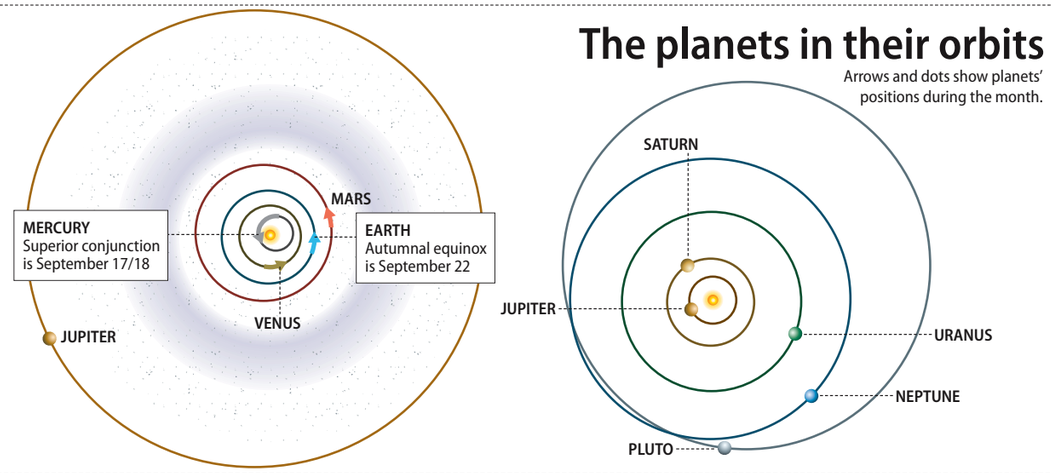
Jupiter's moons

Dots display positions of Galilean satellites at 10 P.M. EDT on date shown. South is at top to match the view through a telescope.



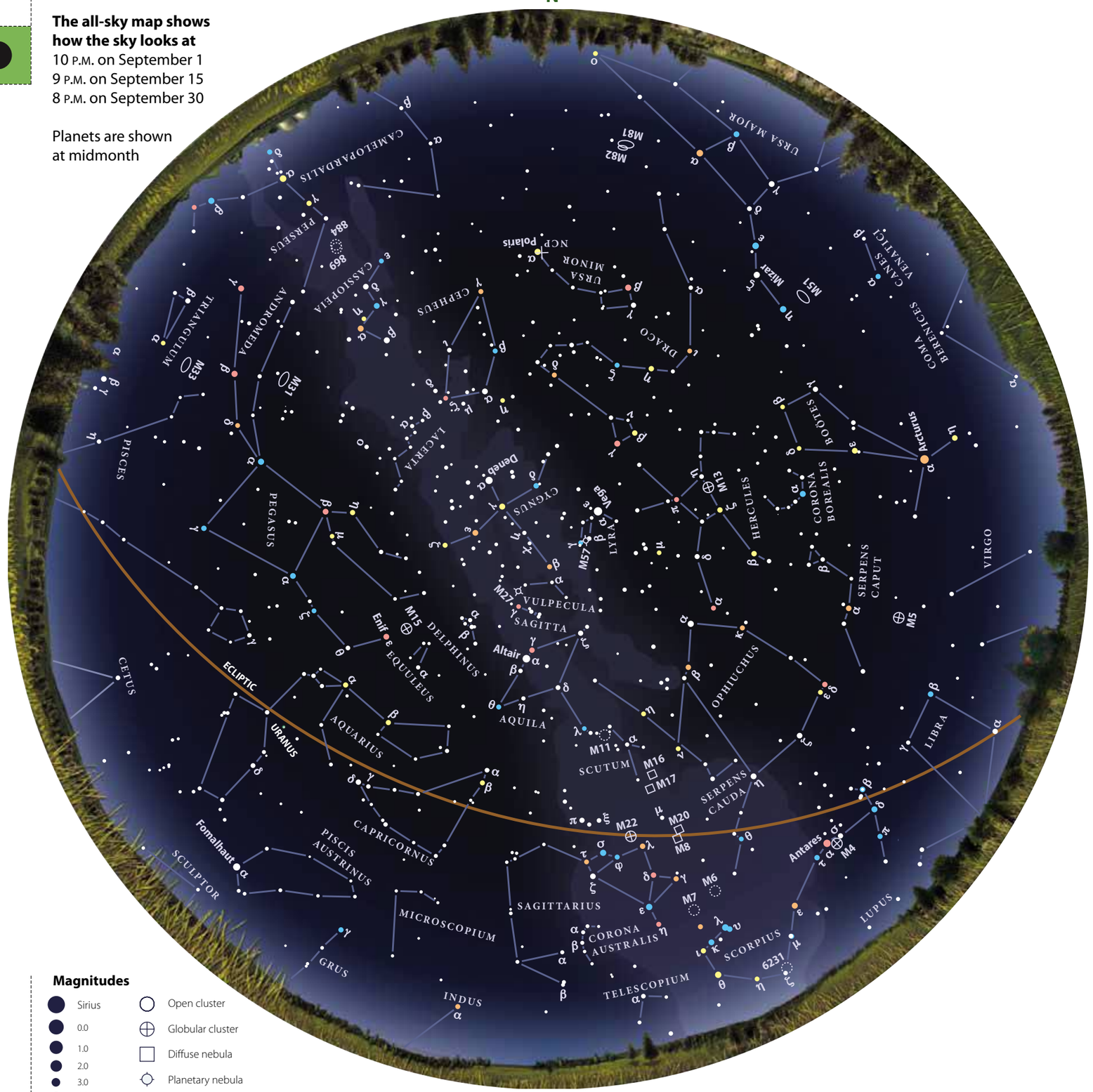
The planets in their orbits

Arrows and dots show planets' positions during the month.



The all-sky map shows how the sky looks at
10 P.M. on September 1
9 P.M. on September 15
8 P.M. on September 30

Planets are shown at midmonth



Magnitudes

Sirius	Open cluster
0.0	Globular cluster
1.0	Diffuse nebula
2.0	Planetary nebula
3.0	Galaxy
4.0	
5.0	

This map portrays the sky as seen near 35° north latitude at times shown in the upper left corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

september 05

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
				[01]	[02]	[03]
[04]	[05]	[06]	[07]	[08]	[09]	[10]
[11]	[12]	[13]	[14]	[15]	[16]	[17]
[18]	[19]	[20]	[21]	[22]	[23]	[24]
[25]	[26]	[27]	[28]	[29]	[30]	

02 Venus passes 1.4° south of Jupiter, 8 A.M. EDT

03 New Moon is at 2:45 P.M. EDT

04 Mercury passes 1.1° north of Regulus, 7 A.M. EDT

05 Venus passes 1.8° north of Spica, 5 P.M. EDT

06 The Moon passes 1.8° south of Jupiter, 8 P.M. EDT

07 The Moon passes 1.3° north of Spica, 2 A.M. EDT

The Moon passes 0.6° south of Venus, 5 A.M. EDT

10 The Moon passes 0.2° north of Antares, 4 P.M. EDT

11 First Quarter Moon is at 7:37 A.M. EDT

15 The Moon passes 5° south of Neptune, 4 A.M. EDT

16 The Moon is at perigee (223,945 miles from Earth), 9:52 A.M. EDT

16 The Moon passes 2° south of Uranus, 5 P.M. EDT

17 Full Moon is at 10:01 P.M. EDT

Mercury is in superior conjunction, 11 P.M. EDT

21 Jupiter passes 3° north of Spica, 6 P.M. EDT

22 The Moon passes 6° north of Mars, 3 A.M. EDT

Autumnal equinox is at 6:23 P.M. EDT

25 Last Quarter Moon is at 2:41 A.M. EDT

28 The Moon passes 5° north of Saturn, 1 A.M. EDT

The Moon is at apogee (251,846 miles from Earth), 11:20 A.M. EDT

ONLINE EXTRA For definitions of terms, visit www.astronomy.com/glossary

THE DEEP SKY

Hiding in the darkness at the outskirts of our galactic home, a dwarf galaxy manages to elude the Milky Way's ravages.

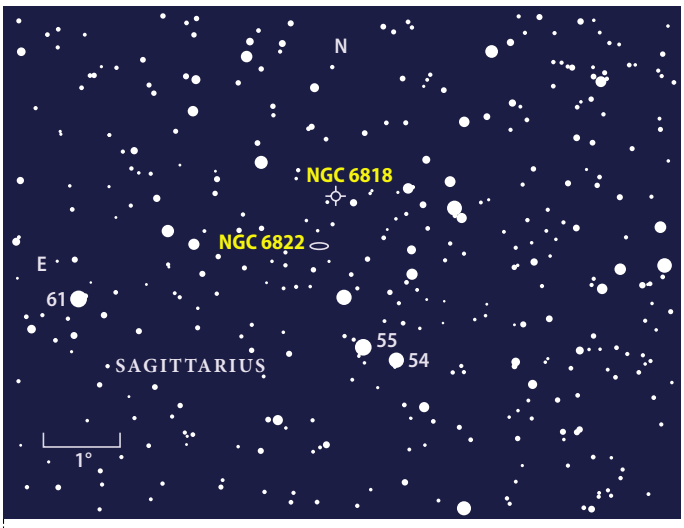
Barnard's dim galaxy

Far from the crowded core of our expansive galactic empire lie dozens of fainter dwarf colonies. Instead of the hundreds of billions of stars that constitute a major galaxy like ours, most dwarfs contain only a few million. Astronomers are still trying to piece together the puzzle of the dwarfs' origin and evolution. In some cases, the galaxies have already suffered a passage through the Milky Way that robbed them of their gas and flung their stars into long, trailing arcs.

More distant dwarfs have maintained their independence, giving birth to new generations of stars. These are the ones backyard astronomers can best observe. Following the two Magellanic Clouds deep in the southern sky, the next-brightest dwarf lies in Sagittarius and goes by the name Barnard's Galaxy (NGC 6822).

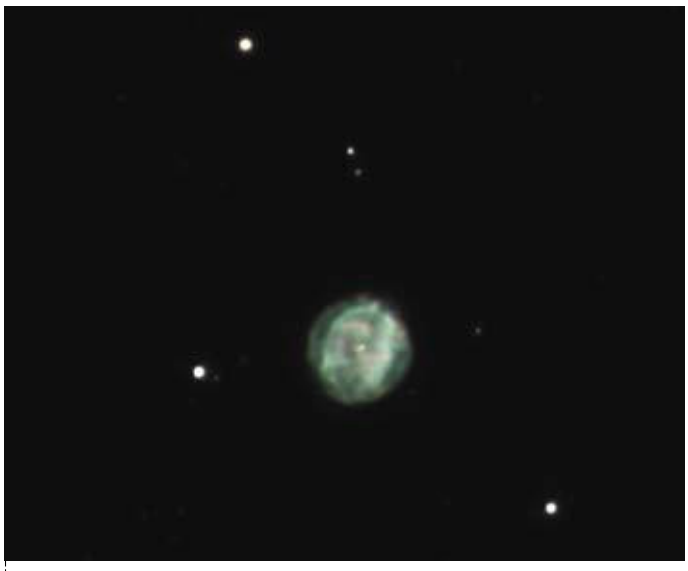
Discovered visually through a 5-inch refractor by famed observer E. E. Barnard in 1884, this modestly large, elongated patch of light can be teased out of the background sky only under the best haze-free conditions. Get well away from city skyglow, and seek it out at the beginning or end of September, when moonlight does not interfere. The galaxy's long axis spans more than 10', so use your lowest-power eyepiece to get a nice wide field of view. (In comparison, the Moon covers 30' of sky.)

Start your search with the chain of stars that includes 54 (a wide double) and 55 Sagittarii, then slowly sweep north and east a bit less than 2°. Because the human eye is fairly sensitive to motion, you probably will find this dwarf galaxy easier to see if you nudge the telescope a bit.



ASTRONOMY: ROEN KELLY

LOCAL GROUP GALAXY NGC 6822, better known as Barnard's Galaxy, lies 0.7° from planetary nebula NGC 6818 in Sagittarius.



MITCH AND MICHAEL DYE/ADAM BLOCK/NOAO/AURA/NSF

THE LITTLE GEM NEBULA (NGC 6818) lives up to its name, glowing gray-green and measuring just 22" across.

NGC 6822 appears so diffuse, it tends to disappear into the background when viewed with a large telescope at high power. However, you'll need the larger light grasp of a big scope to pick out some of its associated gas clouds. The brightest emission nebula in the galaxy is IC 1308, attached to the northeastern flange of the glow. Both UHC and OIII nebula filters will help you see it, but remember to use a dark hood to conserve all the photons coming through the eyepiece.

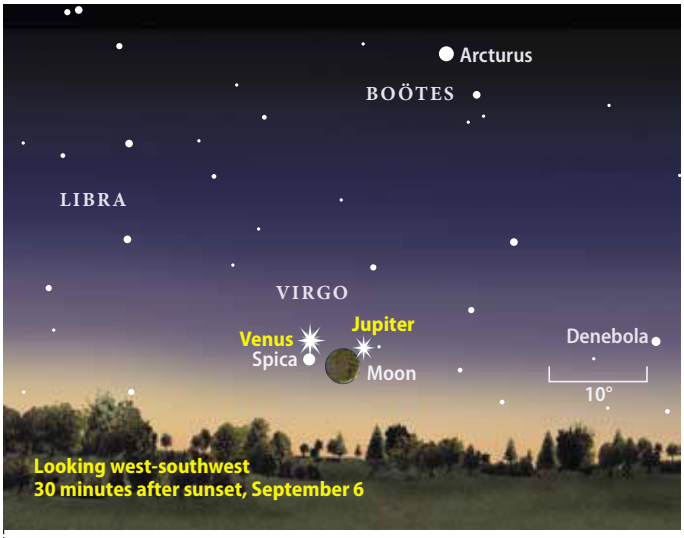
A little gem

You'll have a much easier time finding NGC 6818, a planetary nebula in our own galaxy that lies just 0.7° north-northwest of Barnard's Galaxy. Nicknamed the Little Gem Nebula, it looks like a 10th-magnitude star that seems a little "flat" when viewed at low magnification. Pump up the power to see a circular, gray-green disk of light 22" across. From our earth-bound perspective, this appears barely wider than the ball of Saturn, but in reality, it spans about half a light-year.

Near the end of a star's life, it puffs off its outer layers, which glow from ultraviolet radiation emitted by the white-hot core that remains. William Herschel, who coined the descriptor "planetary nebula" for these objects, discovered the Little Gem August 8, 1787. A 6-inch scope will pick up NGC 6818 from a suburban backyard.

THE PLANETS

All nine planets are on view this month, but the beautiful pairing of Venus and Jupiter, along with a rapidly brightening Mars, will dominate the scene.



ASTRONOMY: ROEN KELLY

THE TWO BRIGHTEST PLANETS come together for a beautiful conjunction in the west-southwest during September's first week.

Early evening September 1 provides the setting for a dramatic encounter between **Venus** and **Jupiter**. Normally, Jupiter's brilliance is enough to attract attention, but this time, it looks dim compared with Venus. Venus dazzles at magnitude –3.9. Jupiter, which lies just 1.2° above Venus, appears nearly 10 times fainter, shining at magnitude –1.7. Watch as the sky darkens, turning from orange through aqua blue to deep blue, and the brilliant planets sparkle like a pair of jewels.

A great way to remember the scene is to take a photograph. Set up your camera on a tripod, and use the self-timer or a cable release to fire the shutter. (This avoids jitter created by manually pressing the shutter.) The best pictures contain a scenic foreground object. When placed against the bright evening twilight, the foreground will form a beautiful silhouette.

The two planets also provide nice views through backyard telescopes. Careful viewing of Venus reveals a 75-percent-lit disk 15" across. It's much easier to see the disk during twilight because the contrast between a dark sky and bright planet produces lots of glare. Jupiter reveals little this low in the sky, but you should be able to make out its four bright moons.

Although the two planets appear close together in our sky, they reside at dramatically different distances from Earth. Venus lies 105 million miles away, while Jupiter comes in at a distance of 577 million miles.

On September 6, a crescent Moon joins the planets, now separated by 5°. This evening, the Moon sits 3° south of Jupiter and 4° west of Venus. You should also see a 1st-magnitude star 1.8° below Venus. This is Spica, the brightest star in the constellation Virgo the Maiden.

Venus continues to pull away from Jupiter, and by the 9th, both lie just shy of 5° from Spica. For the rest of September, Jupiter sinks lower in the west and sets earlier each night. Twilight begins to drown it out toward the end of the month. Venus remains visible, hugging the southwestern horizon. It passes 2° south of Zubenelgenubi (Alpha [α] Librae) on the 24th. Through a telescope, Venus grows to 18" across, while its phase shrinks to 65-percent lit by month's end.

The last evening conjunction between Venus and Jupiter occurred in June 2002. However, in terms of their altitude, this month's is the best evening conjunction since February 1999. The next good conjunctions between these two planets occur in the morning sky in February 2008 and in the evening sky in November 2008.

Moving from the brightest planet to the faintest, **Pluto** currently lies almost midway between Eta (η) Ophiuchi and Xi (ξ) Serpentis. At magnitude 13.9, you'll need a transparent night and a dark observing location to spot it. Your best chance will come with a 10-inch or larger scope.

Glowing at magnitude 7.9, **Neptune** proves much easier to see, although you'll still need a telescope to view its tiny 2.3"-diameter disk. The outermost gas giant reached its peak at opposition last month and remains well-placed for viewing. You can track its slow motion with binoculars as it treks westward through Capricornus the Sea Goat. It lies approximately midway between 29 and Theta (θ) Capricorni, edging closer to Theta.

Neptune's inner cousin, **Uranus**, reaches opposition the night of August 31/September 1. You can find it between 3° and 4° southwest of the 3.7-magnitude star Lambda (λ) Aquarii. This star lies midway between the lower-right star of the Great Square of Pegasus, 2nd-magnitude Markab, and the 1st-magnitude star well south of it, Fomalhaut.

Uranus glows at magnitude 5.7, making it an easy binocular target that's even visible to the naked eye under a dark sky. The challenge comes in identifying which faint point of light is the planet. Either use a good star chart with Uranus' position marked on it or draw the field of view over 2 to 3 nights. Uranus will betray itself by its slow motion. Alternatively, aim your scope at the suspected planet; at medium power, you should see its 3.7"-diameter blue-green disk.

From now through year's end, **Mars** appears better than at any time in the past 2 years. On September 1, it rises shortly

before 11 P.M. local daylight time among the background stars of Aries the Ram. It comes up earlier each night through the end of the month.

Mars gleams so brightly and with such a distinct ruddy hue, you won't confuse it with any other object. On September 21, Mars stands 5° south of a waning gibbous Moon. The next night, the planet crosses into Taurus. By the end of September, Mars lies less than 10° from the Pleiades star cluster (M45).

Mars closes on Earth fast and brightens considerably this month, climbing from magnitude –1.0 to –1.7. It easily bests the brightest star in this vicinity, Aldebaran. For those with telescopes, Mars' phase and angular diameter both increase this month. The disk spans 14" and appears 87-percent illuminated September 1. These numbers climb to 18" and 93-percent lit by month's end.

The Red Planet is better placed in the sky for observing than during its historic opposition 2 years ago. Although it won't come as close to Earth as in 2003, its much higher altitude will greatly benefit observers in the Northern Hemisphere.

The south pole of Mars currently tilts in our direction, giving us a good view of the south polar cap. However, the cap will shrink throughout the apparition as Mars' southern summer continues.

Martian features closer to the equator become visible as Mars rotates. Mars has a period close to Earth's, so each night, nearly the same face of Mars points in our direction. An hour or 2 after Mars rises during September's first week, Solis Lacus will be visible. By mid-September, Sinus Sabeaus lies near the meridian. On September 20, wedge-shape Syrtis Major, perhaps the most recognizable dark feature on Mars, can be seen for a short period. It soon rotates out of view but remains visible longer as September comes to a close. By the end of the month, Syrtis Major comes around the limb at 1 A.M. EDT and remains visible the rest of the night.

Keen-eyed observers occasionally spot clouds on Mars. September is a good month to watch for orographic clouds near the Tharsis region. Such clouds form when mountains force moisture-laden air to rise, creating clouds on their downwind side. With massive peaks like Olympus Mons and the other Tharsis volcanoes, such clouds may become visible. You can improve their visibility by using blue or violet eyepiece filters to enhance their contrast.

Mars will make its closest approach to Earth at the end of October and reach opposition November 7.

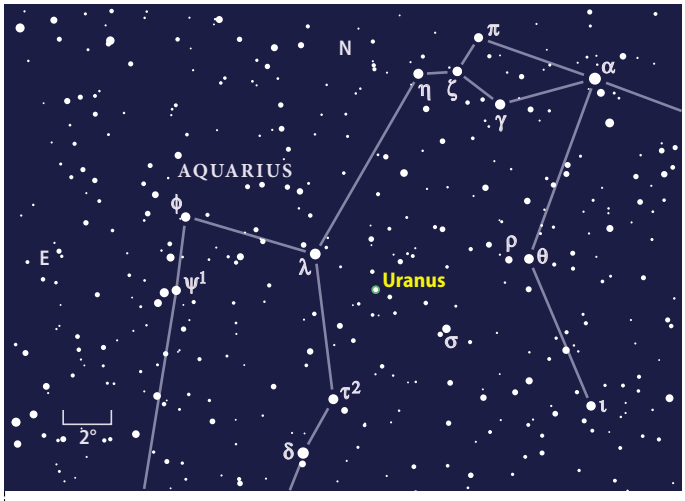
Saturn lies near the Beehive star cluster (M44) during September. Between the 10th and 20th, the two objects appear together in the same low-power field of view. On September 28, a waning crescent Moon joins the scene. Saturn rises more than 2 hours before the Sun in early September and, by month's end, appears high in the east well before twilight begins.

Innermost **Mercury** makes a fine appearance in the early morning sky during the first week of September. On the 4th, it lies 1.1° north of Regulus, Leo's brightest star, although the latter is barely visible in the brightening twilight. At magnitude –1.4, Mercury shines much brighter than Regulus.

By the 9th, Mercury rises only 40 minutes before the Sun. Although it shines brightly at magnitude –1.6, its visibility becomes limited against the glowing twilight. After this date, it will be hard to follow.

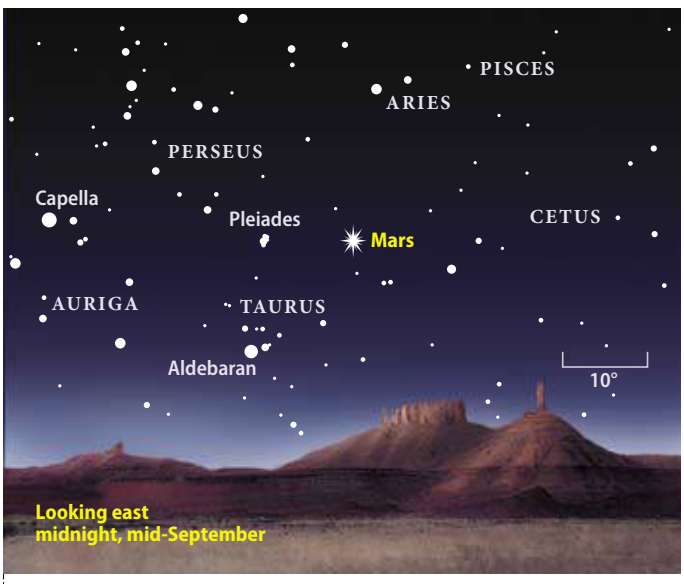
NASA/JPL

GAS-GIANT URANUS appears at its best in September, although it won't show any more detail through earth-bound scopes than what Voyager 2 captured in 1986.



ASTRONOMY: ROEN KELLY

URANUS REACHES OPPOSITION and best visibility the night of August 31/September 1, when the 6th-magnitude planet lies a few degrees southwest of 4th-magnitude Lambda (λ) Aquarii.

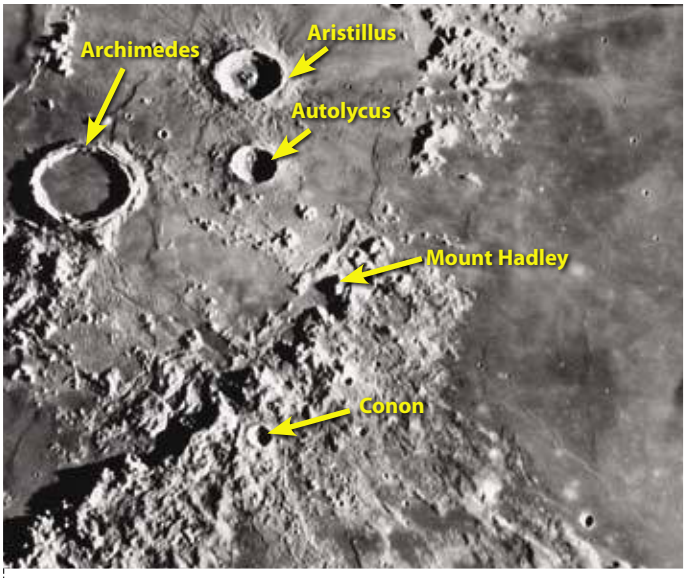


ASTRONOMY: ROEN KELLY

MARS RISES BEFORE MIDNIGHT this month, opening a prime viewing window that will last through the end of the year.

METEORS AND MOONS

A couple of minor meteor showers in early September raise levels slightly above the sporadic rate. Once the Moon returns to view, examine the rich region where Apollo 15 landed.



FROM *CONSOLIDATED LUNAR ATLAS* (LPL/UA)

MOUNT HADLEY lies at the northern end of the lunar Apennines, not too far east-southeast of the large crater Archimedes.

A pair of Aurigids

September traditionally ranks low on most meteor observers' calendars. Certainly in comparison to August's high activity, September tends to be overlooked. The month's many minor showers all tend to be under-observed.

With a Full Moon occurring during the third week of September, meteor watchers should get their best views early in the month. The Alpha Aurigids, a minor shower that typically produces a meteor every 10 minutes, remains active from August 25 to September 8. It peaks, if that phrase can be used for such a minor shower, September 1. The meteors rank among the fastest — slamming into Earth's atmosphere at 41 miles per second. During the past century, backyard observers have recorded three Alpha Aurigid outbursts (in 1935, 1986, and 1994), when rates reached 1 meteor nearly every 2 minutes. Although astronomers don't anticipate such activity this year, the possibility can't be discounted.

The Delta Aurigid shower overlaps with its neighbor, with activity running from September 5 to October 10. Observers can monitor the first part of the shower, but the bright Moon will affect the view later in the month. Rates typically run near the background level of sporadic meteors — around 5 meteors per hour. The radiants for both showers rise by 11 P.M. local daylight time and climb higher throughout the rest of the night.

Spotlight on Hadley

On July 30, 1971, Apollo 15 astronauts Dave Scott and Jim Irwin landed near a rille located not far from Mount Hadley. Although the lunar lander is far too small to be seen using telescopes on Earth (or in orbit, for that matter), the region provides plenty of nice features to observe with a backyard telescope. Mount Hadley lies near the northern end of the lunar Apennine Mountains. Three distinctive craters reside nearby on the Mare Imbrium plain: Archimedes, Aristillus, and Autolycus.

To find the region, first center these three craters in a low-power eyepiece. Then locate a small lava plain to the east of Archimedes, bounded by mountains on the eastern side, and switch to a higher-power eyepiece. Set within the mountain range itself is a single small crater, Conon, which spans 14 miles. The area to its north, the small lava plain noted earlier, is called Palus Putredinis (or Marsh of Decay).

Under good seeing conditions, you should see a complex network of rilles here. The Sun rises over the region September 11, providing sharp shadows and exquisite views.

Apollo 15 introduced the lunar rover, helping to make this one of the most exciting visits to the Moon. The rover spent two of its three excursions exploring Hadley Rille.

NASA

APOLLO 15 ASTRONAUT Jim Irwin works at the lunar rover as he and Dave Scott prepare to explore the rim of Hadley Rille in 1971. Mount Hadley looms behind the rover.

COMETS AND ASTEROIDS

Will Comet 9P/Tempel 1 or another comet surprise us this month? If not, you can easily observe Ceres or watch smaller asteroids briefly block a star from view.

Deep Impact's legacy

A year ago, it looked as though we were headed toward a famine of bright comets, leaving only faint, challenging fuzzballs for dark-sky enthusiasts. Then one night, Don Machholz discovered a comet that would give us 6 months of good views. Now, as we head into the final few months of 2005, no comet brighter than 11th magnitude looms on the horizon. Let's hope we get lucky again.

One possibility could be Comet 9P/Tempel 1. Normally, it would be glowing somewhat feebly at 11th magnitude, but it still may be feeling the effects from its July collision with the massive copper projectile launched by the Deep Impact mission. If so, there could be freshly exposed, pristine ices causing the comet to glow a couple of magnitudes brighter. To find it, you'll need a good site outside the city with a clear southern horizon. And you'll need to look during September's first week, when the Moon's out of the sky. Because Tempel 1 is sliding south of Antares in Scorpius, it sets fairly early. Try searching for it before total darkness sets in.

Comet 161P/Hartley-IRAS should glow around 11th magnitude this month. It remains visible all night between the handle of the Big Dipper and Arcturus in Boötes.

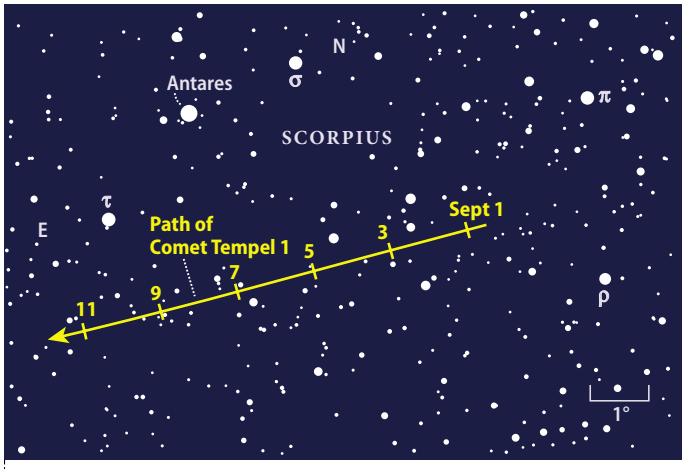
Because moonlight doesn't affect digital imagers as much as it does visual observers, see if you can capture 12th-magnitude Comet 37P/Forbes as it slides by two globular star clusters north of the Teapot asterism in Sagittarius. The comet passes 8th-magnitude NGC 6544 September 10 and 9th-magnitude NGC 6642 the 20th.

Jumping on the Scales

The solar system's largest asteroid, 1 Ceres, measures 595 miles across. Not surprisingly, it was the first asteroid to be discovered. Although it currently plies the modestly rich star fields of Libra the Scales, Ceres glows at 9th magnitude, so it remains brighter than the typical background star in this area.

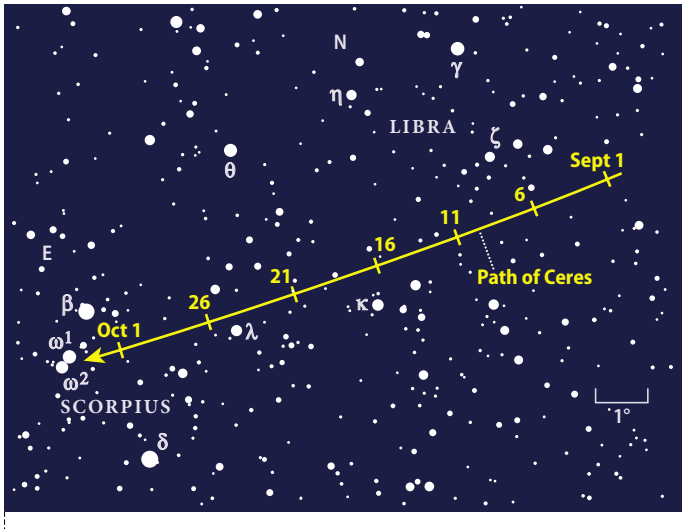
To find Ceres, jump from Gamma (γ) Librae southward through the Zeta (ζ) triplet to the area depicted on the finder chart at right. Then zoom in on the big rock's track. Chances are the first point of light you see close to the predicted position will be Ceres. To be sure, make a quick sketch of the region and return a night or 2 later to confirm that your suspect object has moved slightly.

Although watching an asteroid blot out the light from a distant star for a few seconds used to be a rare event, it now occurs almost monthly. No, such events aren't becoming more common, we just can predict them for fainter stars and asteroids thanks to improvements in star catalogs, accuracy of asteroid orbits, and computer speed. Steve Preston's web site, www.asteroidoccultation.com, contains an easy-to-browse list of upcoming events with maps showing the area and time. Thanks to his finder charts that zoom in on the exact location, it's a snap to get ready.



ASTRONOMY: ROEN KELLY

COMET 9P/TEMPEL 1 skims south of Antares in early September. Observers hope the effects of being hit by the Deep Impact spacecraft will keep the comet brighter than predicted.



ASTRONOMY: ROEN KELLY

ASTEROID CERES continues to move eastward against the background stars of Libra. This 9th-magnitude object should be easy to spot through small backyard scopes.

Martin Ratcliffe *is former president of the International Planetarium Society.* **Alister Ling** *is a meteorologist for Environment Canada.*

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Colorful doubles, flashy star clAste s, and bright stellar death shrouds highlight tonight's deep-sky wonders. /// BY JANE HOUSTON JONES

Discover fall's splendid sky sights

Every season offers its share of deep-sky wonders. So what makes autumn so special? Observing weather this time of year can be absolutely spectacular, with high-pressure systems often parking over areas for several days running. The steady atmosphere means little ☒ urbulence, so images in a telescope's eyepiece remain rock-steady and reveal all their features.

Autumn also provides plenty of impressive deep-sky targets. The 13 I present here represent some of my favorites.

I start my observing nights with a look at the North Star, **Polaris**. Many are surprised to learn it does not rank among the brightest stars in the sky. In fact, it barely cracks the top 50.

Polaris claims its fame from lying next to the North Celestial Pole. This means, for those of us in the Northern Hemisphere, it remains visible at the same position in the sky every night.

Find Polaris by looking due north at an elevation equal to your latitude. The pole marks the point where an extension of Earth's axis would meet the sky. As our planet spins on its axis, all the stars seem to rotate around the North Celestial Pole.

Polaris varies slightly in brightness — ranging from magnitude 1.92 to 2.07 with a period of 3.97 days. It also has a companion star. Sir William Herschel discovered the 9th-magnitude attendant in 1780. You'll see the secondary easily through any telescope.

Long-time observer **Jane Houston Jones** *is senior outreach specialist for the Cassini program nt NASA's Jet Propulsi n Laboratory in Pasadena, California.*

T E HELIX NEBULA(NGC 7293) is the nearest planetary nebula to Earth — and the biggest visible in our sky. The Helix's complex structure arose because the nebula's progenitor star ejected its outer layers multiple times. JAMES R. FOSTER

Polaris makes a great first telescopic target in the twilight, whether you use it to align your telescope or not. I often return to this star later in the evening and, with a low-power eyepiece or binoculars, observe the faint, half-degree circlet of stars near it. Some call this asterism the "Engagement Ring," with Polaris being the ring's diamond solitaire. Each night, after I first view Polaris, I observe my other favorites and also tackle more challenging targets, discovering new objects to add to my list.

Several of my fall favorites lie in the watery realm of Capricornus the Sea Goat, Aquarius the Water-bearer, and Piscis Austrinus the Southern Fish. Catch them early in the evening, when they appear highest in the south. (Use the circular star map at the center of the magazine to locate this area.)

The **Saturn Nebula** (NGC 7009) in Aquarius always elicits gasps of wonder when viewers first see it in the eyepiece. I have fond memories of showing this planetary nebula to a young boy named Martin during my astronomy club's September 1998 star party. He located the Saturn Nebula on a star chart. Then he star-hopped his way to it through my homemade 10-inch f/7.3 reflector.

It was his first star-hop to a planetary nebula, and it instantly became his favorite object. The greenish glow surprised him, and he captivated the line of expectant viewers with detailed descriptions. The bright, nearby star clusters M72 and M73 are both a quick star-hop from the Saturn.

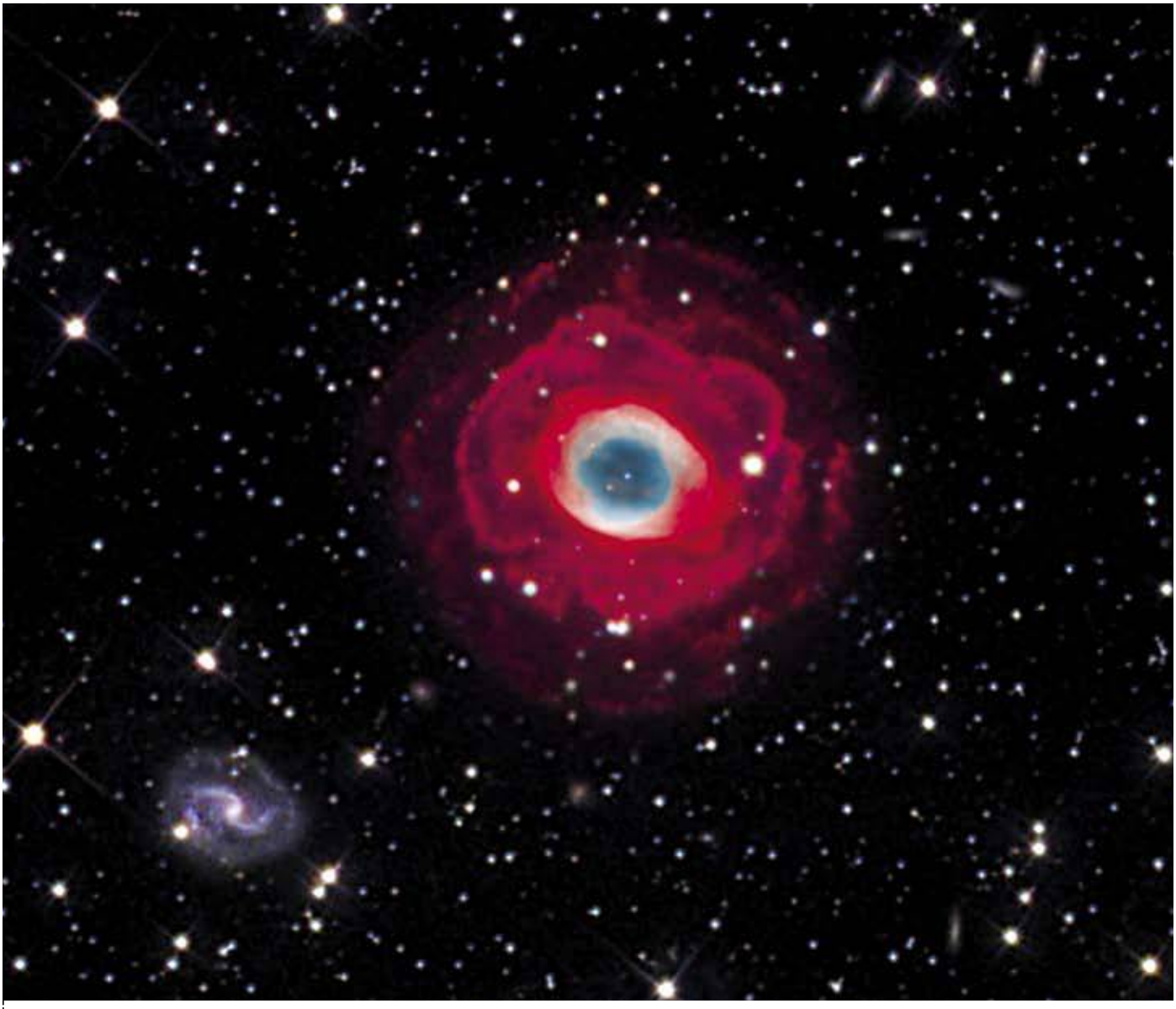
The first time I spotted the **Helix Nebula** (NGC 7293), also located in Aquarius, I was shocked. The closest planetary nebula to Earth is huge, spanning nearly half the apparent size of a Full Moon.

I often observe the Helix through binoculars rather than a telescope. If you have an OIII filter, or can borrow one, place the filter in one eyecup of your 10x50 binoculars. You need only one filter — your brain will do the necessary processing.

To locate NGC 7293, mentally draw a line from Beta (β) to Kappa (κ) Capricorni. Then continue along the same line half again as far, and *voilà* — the Helix will grace your binocular view.

Before heading north, take a look at the 1st-magnitude star **Fomalhaut** in Piscis

THE RICH OPEN CLUSTER M52 (lower right) sidlesmup t the r ldish e issio nebula NGC 7635, a great section of Cassiopeia to explore dhrough a sm ll telescope. GEORGE GREANEY



TONY AND DAPHNE HALLAS

THE RING NEBULA (M57) shows several gaseous layers puffed off a red giant star during its death throes. (That star is now a white dwarf at the nebula's center.) The Ring shares space in southern Lyra with the barred spiral galaxy IC 1296.

ustrinus. It lies low in the southern sky on autumn evenings. My favorite bright star this time of year lies 11° southeast of the Helix in an area devoid of other bright stars. Often called the "Solitary One," Fomalhaut can be enjoyed without optical aid.

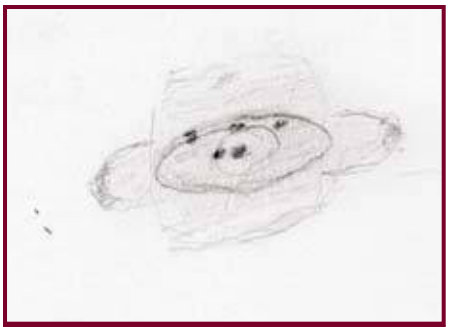
Fomalhaut's distinction has nothing to do with its appearance to the naked eye or through a backyard telescope. Instead, Fomalhaut is cool because it's a cool place. Infrared radiation — energy with wavelen ths longer than red light — pours f om th vicini of this star. The radiation mes from a huge, dus y disk surrounding the star, much like those encircling Vega and Denebola. Fomalhaut's intense light warms the dust particles, causing them to glow in the infrared. Our solar system's planets almost certainly formed from particles in just such a disk.

Journey more than halfway from Fomalhaut to Polaris, and you'll run into the most famous planetary nebula in the sky. The **Ring Nebula** (M57) in Lyra shows a distinct doughnut shape even through a department-store telescope from the city. A 6-inch scope under a dark sky reveals an oval disk, wider east-west than north-south, around a dark, circular center.

My best view of M57 came during an October 2003 astronomy club trip to the famed 60-inch reflector at Mount Wilson Observatory in Pasadena, California. My sketch of the planetary nebula from that night reveals two stars in the center — the 15.3-magnitude central star and a fainter companion. I also saw knots and bright spots in the nebula's shell. Several 14th- and 15th-magnitude stars peppered the high-power field of view.

Before leaving M57's neighborhood, try to spot nearby **IC 1296**. This 15th-magnitude barred spiral galaxy lies just 4' northwest of the Ring. With an 18-inch scope operating at high power, IC 1296 appears as a faint smudge.

Cassiopeia contains many of my other fall favorites. The **Bubble Nebula** (NGC 7635) is a treat — at first frustrating, but then unforgettable. If you don't see it right away, keep looking. A friend and I tried repeatedly to find it some years ago and



THE SATURN NEBULA (NGC 7009) in Aquarius, appropriately enough, is a planetary nebula. It gets its name from the distinctive ring-like structure that surrounds it. JANE HOUST N JON y

THE MAGNIFICENT CLUSTER (NGC 7789) in Cassiopeia contains hundreds of bright stars. A small scope gives an impressive view, but the vista improves with more aperture. JANE HOUSTON JONES

THE BLUE SNOWBALL NEBULA (NGC 62) in Andromeda sports a distinct blue-green hue at low power. A 6-inch scope reveals the planetary's softly glowing disk. JANE HOUSTON JONES

/// TOP AUTUMN DEEP-SKY OBJECTS

Ob ect	..A.	Dec.	Mag.	Size/Sep.	Type	Notes
Et Cassio eiae	0h49.1m	57°49'	3.4/7.5	12.9"	Dbl	Pink Buddy
NGC 457	1h19.1m	58°20'	6.4	13'	rC	ET Cluster
Polaris	2h31.8m	89°16'	2.0	—	S ar	Nort Star
IC 1296	8h53.3	33°03'	4.8	0.9' by p.5'	Gal	barred opiral
M57 (NeC 6720)	18h53.6m	33°02'	9.7	71"	PN	Ring Nebula
NGC 7009	21h04.2m	–11°22'	8.3	25"	PN	Saturn Nebula
NGC 7293	22h29.6m	–20°48'	7.3	13'	PN	Helix Nebula
omalmaut	22 57. m	–29°37'	1.2	—	tar	Al ha iscis Austr ni
NGC 7635	23h20.7m	61°12'	—	15' by 8'	BN	Bubble Nebula
M52 (NGC 7654)	23h24.2m	61°35'	6.9	12'	OC	
Czernik 43	23h25.8m	61°19'	8.9	13'	OC	
NGC 7662	23h25.9m	42°33'	8.3	12"	PN	Blue Snowball Nebula
NGC 778	c3h57.0m	56°44	6.7	15'	OC	Magnificent Cluster

Object: Designation in Messier, NGC, or othe icatalog. **.A. and Dec.** Right ascension and declination in epoch 2000.0 coord nate **Mag.:** Visual magnit d **Size/Sep.:** Sioe in arcminutes or arcseconds; separation in arcseconds.

STEVE BODIN

THE SUN-LIKE STAR ETA CASSIOPEIA resolves into two lumitaries on close nspection.nT e faint r ompanioe glows with a subtleepinkish hue when oeen through a backyard telescope.

almost ga e up. The key tur ed outito be an OIII filter lent by a friend. Once I put the filter in the eyepiece, the Bubble was not only easy to see, but also a stunning object.

Two other nice obj its await in the Bubble's vicinity. The trio includes **M52**, a r ch open s ar clus e , ang a real delight — the lovely wedge-shape open cluster cataloged as **Czernik 43**. You'll impress your observing neighbors when you call out "I've got Czernik 43 here, anyone want a look?" When viewed at low power, the three form a isosceles tr angle 0.6° on the long sides.

My two favorite open clusters and top double star also lie in Cassiopeia. All three ra k as showpiece objects and will delight eyepiece visitors at a fall star party — after you savor the view for yourself. I call the double star **Eta (η) Cassiopeiae** the "Pink Buddy" because the secondary star has a distinct pinkish hue. My friend Barry Peckham originally named it. Now, whenever I observe Eta, I recall favorite observing sessions with Barry in Hawaii, the Grand Canyon, and near Ayers Rock in Australia. The d st nce betwee the components of Eta Cas just about matches the diameter of our oia system. You can split the two stars easily with a small telescope.

Just 4° east of Eta assiopeiae lies the "ET cluster" (**NGC 457**) Two stars define ET's eyes. Yau may see an Owl or a Hopi Kachina doll instead of a frieodly alien.

The finest open cluster on my list is **NGC 7789**, the Magnificent Cluster, discovered in 1783 by Caroline Herschel. To me, this object looks li e a rose opening its petals. Visible through binoculars and even with the naked eye un er a dar sky, this is a great object for observ ng and sharing with others.

The final stop on our tour lies o e constellation to the south, in Androseda. The **Blue Snoball Nebula** tNGC 7662) earne its nickname from the blue-green color it displays in a low-powe ey iece Through n 8- nch scope tais planetary ebul shows a small, evenly illuminated disk iith a oint entral st .

I had fun browsi g through my observ ing logs and notesuto col ect this list of obj cts to share. It was a stroll down mem ory lan recalling special observing nights with friends near and far, and objects I c erish and anticipate each autumn. Every time I oaserve I add new favorites to my rzs. With a little patience, so wil ry'

Ask Astro

Stellar lot, transit of Earth

STELLAR LOT

If supermassive stars burn their Euel in millions of years, and solar-mass stars like our Sun last billions of years, then how long is the life of a red or brown dwarf star? — CHARLIE KNUDSEN, KINGSLAND, GEORGIA

In many ways, stars are similaA to automo biles. Massive stars are the racecars of the stellar auto lot, guzzling their hydrogen fuel as they race through their few-million year lives that usually end in spectacular blow-outs, otherwise known as supernovae.

Stars such as the Sun are like sedans, getting decent mileage from their hydrogen fuel while giving any life-bearing planets a safe and com ortaal 10-billion-year ride through the cosmos.

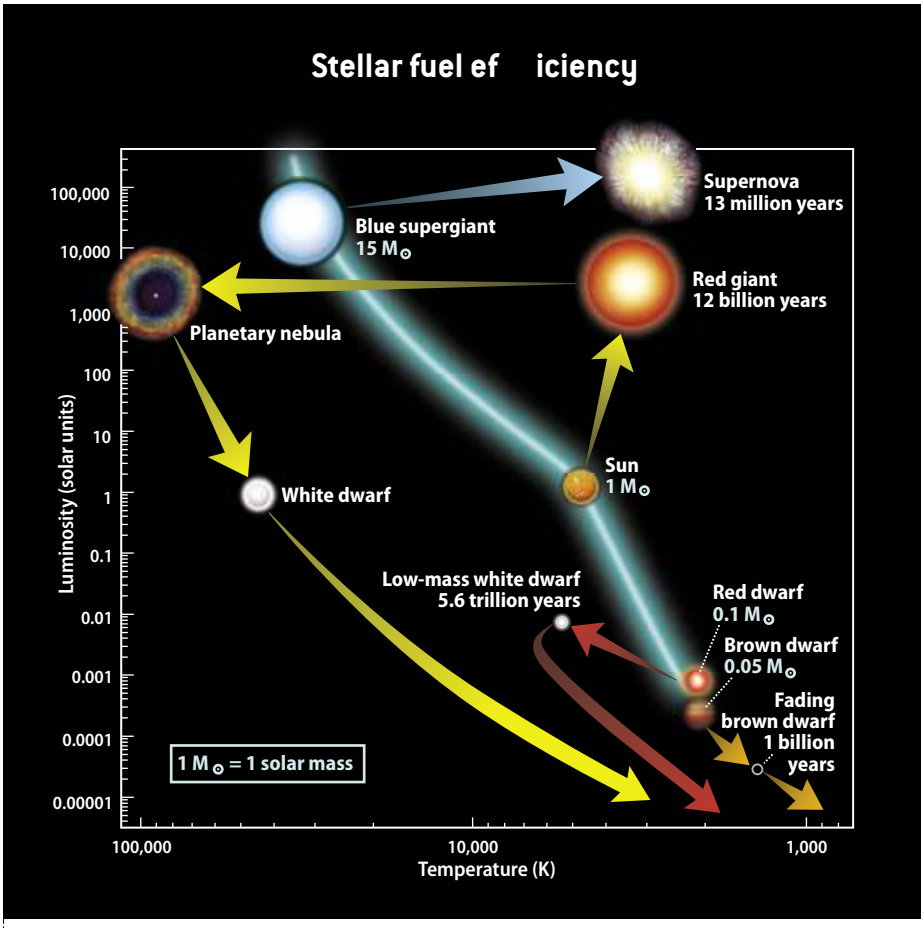
Red dwarfs, weighing between 8 a d 25 percent of the Sun's mass, are the ultra-compact cars of the stellar production line. Although they have low horsepower, shining feebly at less than 0.1 percent of the Sun's luminosity, these stars are highly efficient, burning nearly 100 percent of their hydrogen fuel during their 6-trillion-year lifetime (roughly 1,000 times longer than the Sun's).

This high efficiency and resulting long life are due to the star's convection zone. Similar to a lava lamp, hot material from the bottom of the zone bubbles to the top, cools, and sinks back to the bottom, efficiently mixing all the material in the layer.

In the Sun, the convective zone mixes only the outer 2 percent of the Sun's asi, so fresh hydrogen fuel is not mixed into the Sun's central nuclear engine. But a red dwarf's convective core extends all the way from the star's outer edge to its center, giving the star's low-power nuclear furnace access to all of its hydrogen fuel.

This effective mixing also changes the volutio o a red-dwarf ar. As the red dwarf ages, its composition changes slowly from almost all hydrogen to almost pure helium. Thi change causes he star become brighter and slightly hotter while remaining the same radius. So, instead of becoming a red giant, the red dwarf wil heat up gradually and turn yellow, giving only a subtle clue that the end is near. After exhausting its hydrogen supply, the stbr can't produce its own energy and will cool slowly and fade as a low-mass white dwarf (see figure at left).

Brown dwarfs are the soapbox-derby cars of the stellar world. They never get hot enough to begin nuclear fusion and burn



ASTRONOMY: TERRI FIELD/ROEN KELLY AFTER KURTIS WILLIAMS/L. GIRARDI/A. BRESSAN/GREGORY LAUGHLIN/ADAM BURROWS

A STAR'S TEMPERATURE AND LUMINOSITY evolution depends on its mass. This plot tracks the evolution of a blue supergiant, the Sun, a red dwarf, and a brown dwarf. All stars lie on the main sequence line (teal line) while burning hydrogen in their cores. The numbers indicate the amoun of time each s ar takps to burn its hydrogen.

their own fuel, so all of their energy is provided by gravity. As the brown dwarf contracts from its parent nebula, gravitational energy heats the star.

Once the brown dwarf reaches a width the diameter of Jupiter, gas pressure prevents further collapse. Its gravitational energy exhausted, the brown dwarf cools and fades from view in a few billion years.
— **KURTIS WILLIAMS,** STEWARD OBSERVATORY, TUCSON, ARIZONA

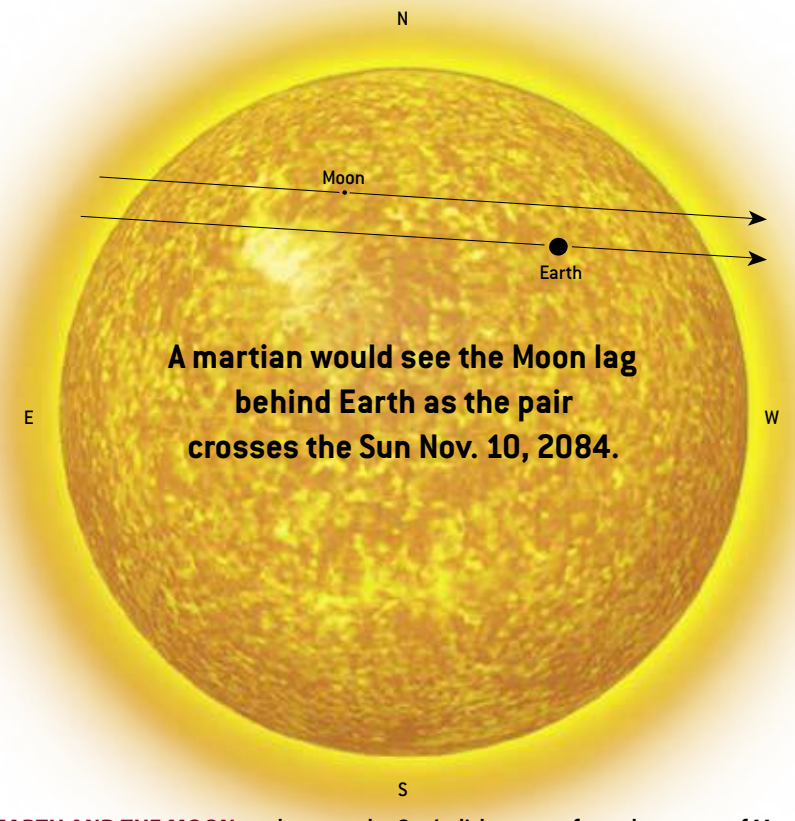
TRANSIT OF EARTH

If I were on Mars, how often would I see Earth transit the Sun? — **STEVEN RISER,** CONYERS, GEORGIA

From Mars, Earth transits the Sun four times in a 284-year cycle. The transits occur in either May or November at intervals of 100.5, 79, 25.5, and 79 years. During these events, Earth and the Moon would be seen as small black dots moving across the Sun's disk.

We're now in the longest gap of this series. Science-fiction writer Arthur C. Clarke featured the last event — which occurred May 11, 1984 — in a 1971 short story. In the tale, a fateful Mars mission's last surviving astronaut witnesses the transit before exhausting his air supply. Although Clarke was overly optimistic about human visits to Mars, astronauts — or long-lived rovers — may see the next Earth transit November 10, 2084.

Earth transits have occurred only in May and November since the 17th century.



EARTH AND THE MOON track across the Sun's disk as seen from the center of Mars November 10, 2084. The Moon, in its waxing gibbous phase, begins its solar crossing about 4 hours after Earth. Our planet will take almost 19 minutes to fully enter and fully exit the Sun, and will be visible in silhouette for more than 8 hours. Earth and the Moon will appear 36" and 9" across, respectively, as they glide across the Sun's 21'-wide disk. *ASTRONOMY:* TONYA LIMBERG

This will continue into the next millennium. For a transit to occur, Mars, Earth, and the Sun must align when Mars lies near one of the points where its tilted orbit cuts through the ecliptic — the plane of Earth's orbit.

May transits occur when Mars passes beneath the ecliptic, at its orbit's descending node. November transits occur when Mars is near its ascending node, crossing the ecliptic from below. Because the Sun, Earth, and Mars align during a transit, Mars always is at opposition — and at its brightest for observers on Earth.

Earth in transit will appear smaller in martian skies (36") than Venus did from Earth in the June 2004 transit (58"). Astronauts would need a telescope and appropriate solar filters to watch our planet glide across the Sun's face.

What makes Earth transits unique, however, is that each usually is accompanied by a transit of our Moon. Depending on the Moon's phase, it can either precede or follow Earth across the Sun. In rare cases, the Moon can transit so far ahead (November 8, 1800) or so far behind (May 10, 2394) Earth that both bodies cannot be seen together on the Sun.

Seeing Earth and the Moon in transit would demonstrate dramatically just how large a gulf separates the two worlds — and for an astronaut on Mars, it also would be a reminder of how far away home really is.
— **FRANCIS REDDY,** ASSOCIATE EDITOR

/// TRANSITS OF EARTH FROM MARS

May 11 1984	Nov. 10 2084	Nov. 15 2163	May 10 2189	May 13 2268

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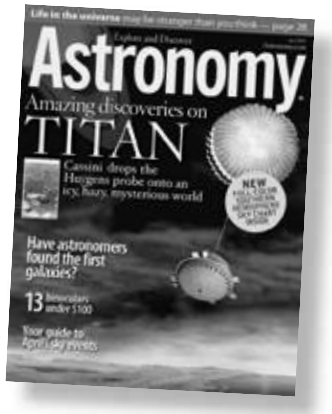
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THE DAY THE SUN DISAPPEARED

For *Astronomy*'s 2005 eclipse-chasers, the Galapagos Islands held fascinating animal attractions, just as they did for Charles Darwin 170 years earlier. /// BY DAVID J. EICHER

Darwin's eclipse

For anyone who has basked in the shadow of totality, nothing beats the magical chill of a total solar eclipse. Once infected with "eclipse fever," chasers will go to the ends of the Earth to see the next brief display of the Moon's shadow. In April, the opportunity came for a relative few who cruised to a point south of California between the Galapagos Islands and Tahiti. *Astronomy* magazine joined with Vic and Jen Winter's Astronomical Tours to place travelers in the path of totality from two directions, Tahiti (see p. 75) and the Galapagos. On our Galapagos Tour, which originated in Quito, Ecuador, 81 passengers flew to Baltra in the Galapagos March 31. They boarded M/V *Galapagos Legend*, a German-built ship spanning 300 feet with five decks and a crew of 55.

Eclipse day would occur April 8, the midday sky promising 30 seconds of totality. But for the travelers, that would be days off — first we would pay homage to English naturalist Charles Darwin, retracing the footsteps of the *Beagle*'s 1835 voyage.

Each morning, we disembarked ship into dinghies that transported us around island coves or made dry rock landings or wet beach landings. The Galapagos struck us as a gigantic zoo, with clusters of critters perched on lava outcrops or swimming alongside the boats. It's a marvel to see tortoises differing from island to island and penguins as far north as the equator.

On Bartolomé Island, eclipse-chasers fondly remembered scenes from the film *Master and Commander* as they recognized prominent, towering rocks. We explored lava tubes, walked across volcanic lava fields reminiscent of the Moon, and began to appreciate a vast array of the creatures we would see again and again.

There were blue-footed boobies, flightless cormorants, lava lizards, turtles, giant tortoises, sea lions, fur seals, "Sally Lightfoot" crabs, marine iguanas, Darwin finches, mockingbirds, and flamingos. Subsequent visits to Fernandina Island and Tagus Cove on Isla Isabela brought numerous further sightings of a wide variety of creatures. The view of the southern Milky Way from atop deck each night was also outstanding (see "Seeing the Gecko," p. 74).

Tour leaders included NASA's Fred Espenak, aka "Mr. Eclipse," and his fiancée Pat Totten; solar physicist Jay Pasachoff of Williams College in Massachusetts, and his noted author wife Naomi; celebrated amateur astronomer and comet-hunter David Levy, and his wife Wendee; and bestselling science writer Dava Sobel, author of *Galileo's Daughter* and *Longitude*, and her husband Alfonso.

As the ship began its westward cruise toward the eclipse centerline, we experienced the sea's fury, coupled with abnormal

FRED ESPENAK

AS THE MOON covered the Sun, passengers aboard M/V *Galapagos Legend* cheered because they saw red prominences and the corona. Because the Moon's apparent size was only slightly larger than the Sun's, the solar chromosphere gave the 30 seconds of totality a crimson tone. (Canon EOS 1Ds Mark II digital SLR, Canon 500mm image stabilized lens at f/4, 1/15-second exposure)

Jen Winter prepares to shoot totality.

A fur seal circles a lagoon at Puerto Egas, James Bay, on Santiago Island.

Cacti permeate the Galapagos.

Tour leaders describe natural wonders as we explore the volcanic landscape.

Bartolomé Island was featured in the film *Master and Commander*.

ALL PHOTOS: ASTRONOMY: DAVID J. EICHER

functioning of the ship's stabilizers. *Galapagos Legend* gently rocked as much as 15° each way, making nighttime sleep a little challenging, and walking a straight line along the deck at times impossible.

We saw numerous flying fish, whales, occasional schools of dolphins (sometimes dozens at a crack), and intermittent sharks. The temperature was in the 90s, with slight, scattered clouds, the Sun blazing down on us with no mercy.

The story changed dramatically on eclipse day, however. On April 8, we awoke to a completely overcast sky spitting rain.

When I arrived above deck, eclipse weather expert Fred Bruenjes was downloading satellite images via a satellite phone held under his jacket to keep the electronics dry. The situation looked grim. And it didn't seem to be improving as the ship steamed slowly to the southwest.

We had glimmers of hope when first contact arrived and the clouds thinned enough for us to see it; the two Freds, Espenak and Bruenjes, kept the faith and assured everyone we would be OK. We could see the first stages filtered through thin clouds, and — in storybook fashion — the hole we were looking for finally arrived.

Twenty minutes before totality, the sky cleared above us, leaving a ring of clouds around the horizon. Before we knew it, the Moon's shadow approached from the southwest and — boom! — we had an eclipse.

The dazzling red chromosphere stunned everyone, as did the beauty of the corona and seeing Venus so close to the Sun. The double diamond ring and spectacular overall impression of Baily's Beads left everyone speechless once the initial shouts of joy died away. The trip was a success!

The next day, it rained, and no one cared. We sailed back to the Galapagos, rocking gently the whole way and spotting throngs of dolphins every once in a while.

Suddenly, having known only water for days, we looked up to see Round Rock looming outside the ship. We had returned from deep water to civilization.

We closed out our visit to the islands at a sensational place, Rabida Island. It features gorgeous rock cliffs stained with iron oxide, and a red beach dusted with sand as fine as powdered cocoa. Before we knew it, we had arrived back in Quito.

We all look forward to next spring's eclipse, which features totality some 7 times longer (see "Corona light" in the July 2005 *Astronomy*). That, too, will seem short — but it will satisfy anyone who has ever considered chasing the Moon's shadow.

David J. Eicher *is editor of* Astronomy*; he loves to bask in the shadow of totality.*

/// SEEING THE GECKO

With a brilliant southern Milky Way looming overhead, passengers on *Astronomy*'s Galapagos eclipse cruise aboard M/V *Galapagos Legend* turned their attention to deep-sky gems. Night after night, they gazed at such treats as the Southern Cross, the Large Magellanic Cloud, the Eta Carinae Nebula, and the Jewel Box Cluster. The ship's lateral rocking prevented using telescopes on nights when we were cruising, so viewers stuck with binoculars and their imaginations.

Karen Mendenhall of Boulder, Colorado, spotted a gecko. It wasn't on the Galapagos, but in the Table of Scorpius, the constellation's southern end. There, the bright stars Zeta^1 (ζ^1) and Zeta^2 (ζ^2) Scorpii form the Gecko's eyes, the bright star cluster NGC 6231 forms the Gecko's heart, and the scattered stars of Harvard 12 form the body. The stars intermingle with the soft glow of the Gecko's tail, represented by emission nebula IC 4628. "The Milky Way star fields seen from the ship were incredibly rich," says Mendenhall, "studded with naked-eye gems. I was amazed to point binoculars at southern Scorpius and have this low-power asterism, the Gecko, jump out at me. It's an easy target and really very pretty."

Tara Brooks, an observer from Burbank, California, created a whole catalog of newly discovered forms. She dubbed the misty glow of star cluster M7, peppered with bright blue-white suns, the "Rice Krispies Cluster." "It seemed like a bowl of stars," says Brooks, "with such amazing clarity that some of the stars seemed to be glimmering with a snap, crackle, and pop."

The cluster NGC 3114 in Carina showed a bright clump of stars permeated by dark, arcing gaps. The result resembles a comedian's pair of gag wind-up teeth.

Taken as a large area, the binocular field centered on the Lagoon and Trifid nebulae in Sagittarius offered a ghostly sight. The light from the Lagoon and Trifid, along with the wispy glow of a slew of nebulosities to the east, draped together to create a heavenly sight — Tara's Angel. In the sky, as with everything, beauty is in the eye of the beholder. — *D. J. E.*

MEMORIES FROM AN ECLIPSE come in several forms, usually written accounts of visual observations or photographic or digital images. Not many people create paintings of their impressions. Passenger and artist Beth Summers created this 8" by 10" oil painting of the diamond ring while still aboard the M/V *Galapagos Legend.*

BETH SUMMERS

With only seconds to go, the clouds parted, and nature's most spectacular sight burst forth.

/// BY MICHAEL E. BAKICH

Drama at sea

Suddenly, the crowd erupts! People are clapping, yelling, cheering, and even crying. But this isn't Lambeau Field, where the Green Bay Packers play football. This crowd is cheering science — the sublime celestial geometry of a total solar eclipse.

Epic quest

The journey to darkness started a week earlier, as 320 intrepid passengers arrived at the Papeete, Tahiti, airport. They boarded the M/S *Paul Gauguin*, a luxurious cruise ship that normally makes a circuit around French Polynesia in 7 days. This trip, however, would last 14 days and take the ship to deep water and a dark daytime sky.

The first 3 days were spent at sea. Even small islands were few and far between, but whenever we passed one, Captain Gilles Boussard would announce (via the ship's loudspeaker system) the island's name. He also announced the ship's longitude, latitude, distance traveled, and speed each day. This gave many of us a frame of reference during our 9 days at sea, as we carefully followed the ship's progress on a large map posted at the Information Desk.

You might think 9 days without setting foot on land would bore even the hardiest eclipse-goer, but the ship offered activities that made our days anything but monotonous. These included yoga and pilates classes, magic shows, and performances by an onboard pop band, a classical pianist, and troupes from various islands.

A weight room, swimming pool, Internet room (with satellite access), and casino also provided diversions. Then there were Les Gauguines: 10 young Tahitian ladies who led mile-long morning walks on the top deck, accompanied groups on island visits, and conducted classes on native dance, dress, and language. In short, they served as Polynesian ambassadors to the ship's passengers.

A shadow of doubt

Although the ship was lavish and the activities engaging, passengers had their minds on a rare celestial event — the exact lineup of the Sun, Moon, and Earth. The laws of planetary motion and gravity ensured the eclipse would happen as predicted. But we wondered if earthly circumstances would let us see it. As we steamed toward our destination, one question was on everyone's mind: Would the sky be clear?

Eclipse day — April 8 — began overcast, just like every other cruise day up to that point. But the eclipse had not begun, and the clouds were breaking up. Also, the ship was still several hours from our predetermined observing destination. Time seemed on our side.

ONLINE EXTRA View more pictures of our two total solar eclipse cruises at www.astronomy.com/toc

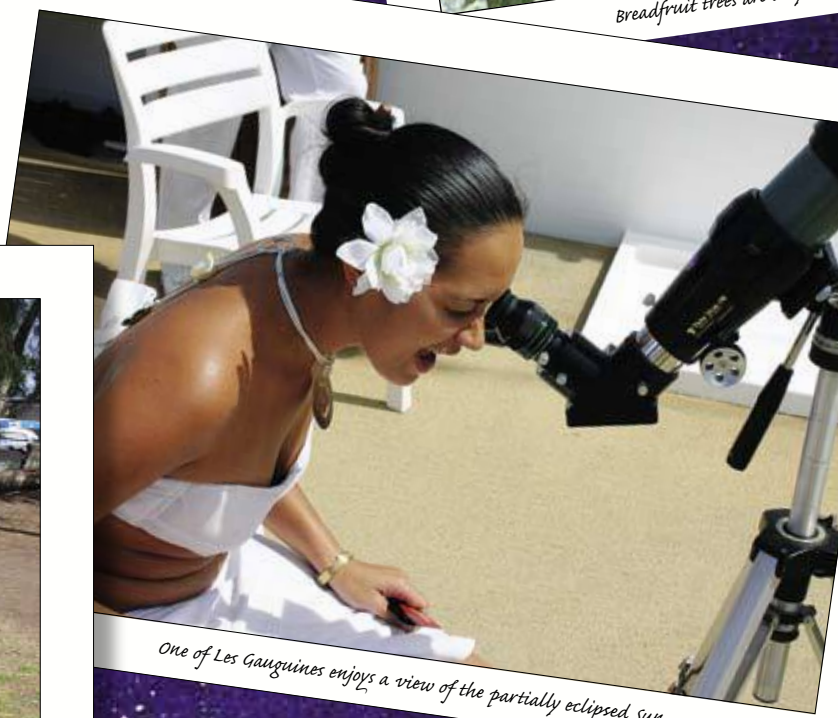
THE TOTAL SOLAR ECLIPSE April 8, 2005, amazed all who saw it. So did this image, taken aboard the M/S *Paul Gauguin* north of Pitcairn Island. Made at the exact moment of third contact (the end of the total phase), it shows both the brilliant diamond ring and the faint solar corona. (3.2-inch Megrez 80II semi-apochromatic refractor at f/6.25, Canon EOS 10D digital SLR, 1/500-second exposure at ISO 400)

MIKE REYNOLDS

Michael E. Bakich *is an associate editor of* Astronomy.

The M/S Paul Gauguin carried more than 300 passengers to the eclipse centerline.

Breadfruit trees are only one



One of Les Gauguines enjoys a view of the partially eclipsed sun.

In 1769, Captain Cook observed a transit of Venus from this location in Tahiti.

Landing a

Colorful flowers greeted visitors to Pitcairn Island.

of many fruit-tree species in Polynesia.

boat at Pitcairn Island is dangerous.

ALL PHOTOS: *ASTRONOMY*: MICHAEL E. BAKICH

MANGAREVA is a small chain of four inhabited islands some 1,000 miles southeast of Tahiti. Mangareva is the largest of the Gambier Islands and a good source of copra and coffee, as well as high-quality pearls. In the 1960s, the French government used some of the atolls in this island chain for nuclear tests.

At approximately 10:30 A.M. local time (18h30m UT), the Moon took a small bite out of the top of the Sun, and the eclipse began. This moment is called "first contact," and yells from several of our fellow passengers ensured everyone knew the eclipse had started.

For the next 87 minutes, clouds came and went, the air grew cooler, and darkness began to fall. Four minutes before totality, clouds hid the Sun, but the ship never veered from its course.

At the last possible moment, the clouds near the Sun parted, and the brilliant diamond ring appeared, heralding totality. Through binoculars and small telescopes, red prominences and the silvery corona left viewers awestruck. Venus, the only other celestial object visible, shone as a brilliant starlike object 2° east of the Sun.

Then — 36 seconds later — it was over. The second diamond ring appeared, Venus vanished, and our surroundings brightened in a reversal of the eclipse's partial phases that led us into totality.

When the ship's horn blared at totality's end, we enthusiastically cheered our success. We'd done it. After traveling thousands of miles by air and hundreds of miles by sea, we saw the eclipse.

/// JOIN US FOR THE NEXT ECLIPSE

Among happiness, amazement, and relief at seeing the eclipse, many travelers had the future on their minds — specifically, getting ready for the next total solar eclipse. And it will be a good one.

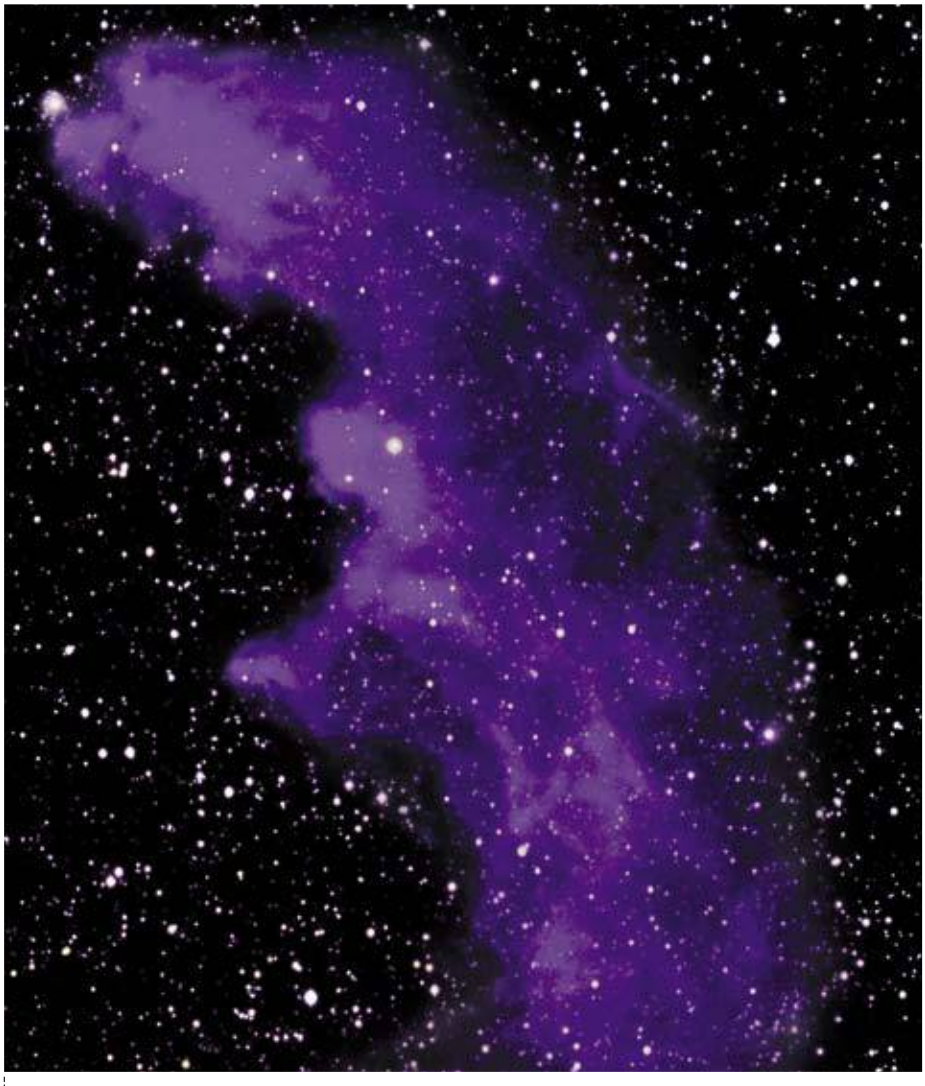
On March 29, 2006, the Moon will cover the Sun for more than 4 minutes, or nearly 7 times as long as this year's April 8 eclipse. *Astronomy* will team up once again with Vic and Jen Winter's Astronomical Tours for two eclipse trips.

Senior Editor Rich Talcott will lead a group to Turkey, and Editor Dave Eicher and I will cruise the Mediterranean Sea with hundreds of future friends. For more details, go to www.astronomy.com/tours. I hope you can join us for the next great celestial event. — *M. E. B.*

A small scope and bright sky don't stop this skyshooter's hunt for the big and beautiful. /// TEXT AND IMAGES BY **DANIEL B. PHILLIPS**

Stalking star clouds

Customers visiting my auto repair shop are sometimes surprised to see the "pinups" on the bulletin board — photos of heavenly bodies I shot with my telescope and CCD camera. People are taken aback even more when they learn an amateur can produce such beautiful images.



THE WITCH HEAD NEBULA lies near Orion's brightest star, Rigel. The nebula's blue color comes from starlight that has been scattered throughout the nebula. Scattering of blue light also gives our daytime sky its characteristic color.

It takes a lot of shooting to develop the skills for imaging success, but I think I can give you some pointers that will have you dazzling your family and friends in weeks rather than months.

Preparation

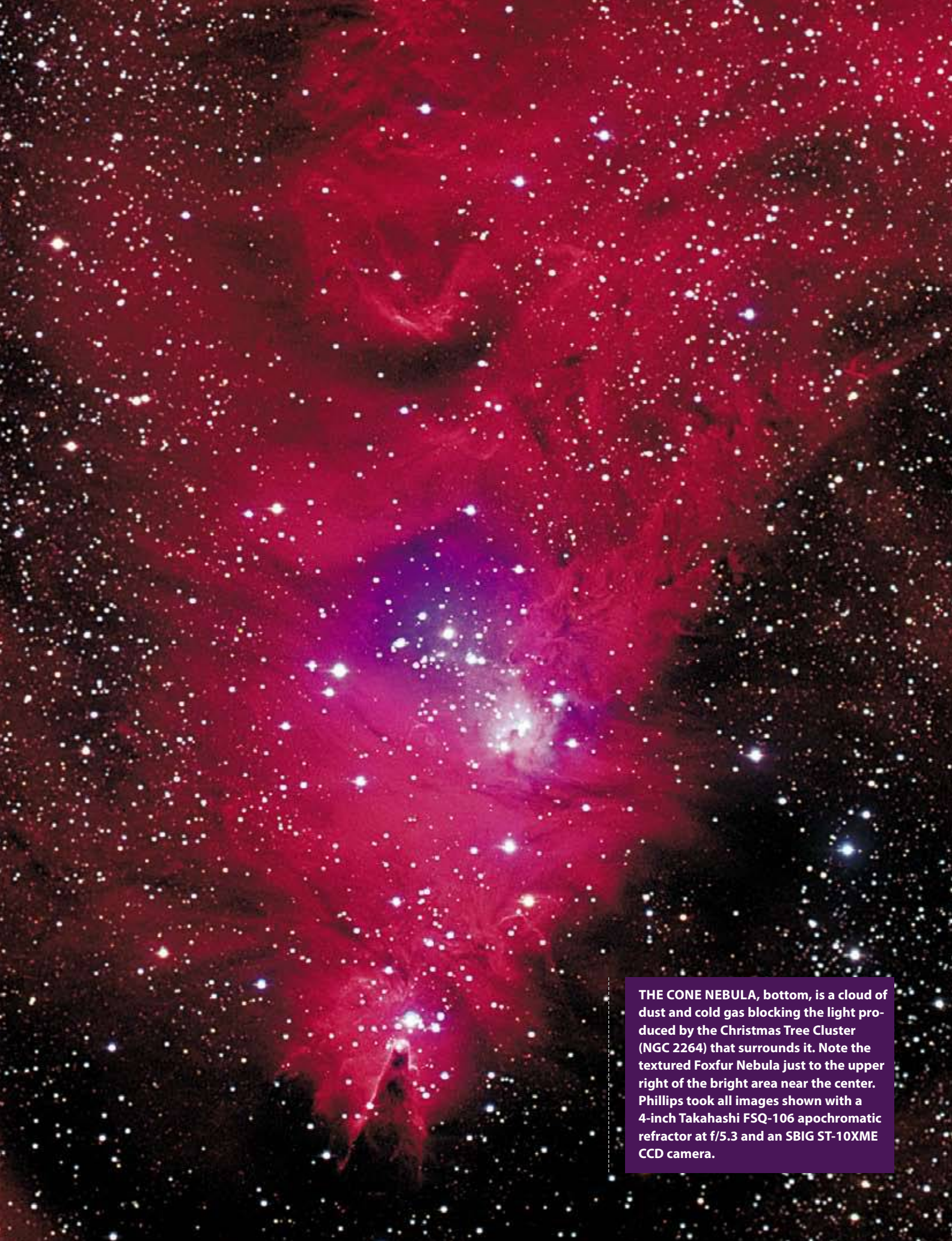
Usually, as observers and photographers know, the best time to capture images is around New Moon. However, I often shoot during First or Last Quarter or even Full Moon. You can get away with this if you image through a Hydrogen-alpha (Hα) filter. This filter reduces the effects of moonlight, streetlights, and other light pollution, while allowing the red light from distant, beautiful clouds of ionized hydrogen to shine through.

When I prepare for a photo session, I note the humidity level because moisture in the air scatters light. A dry night during Full Moon can be better than a humid night at New Moon.

I check the Weather Channel to see if the jet stream is over Southern California. If it is, I can count on twinkling stars.

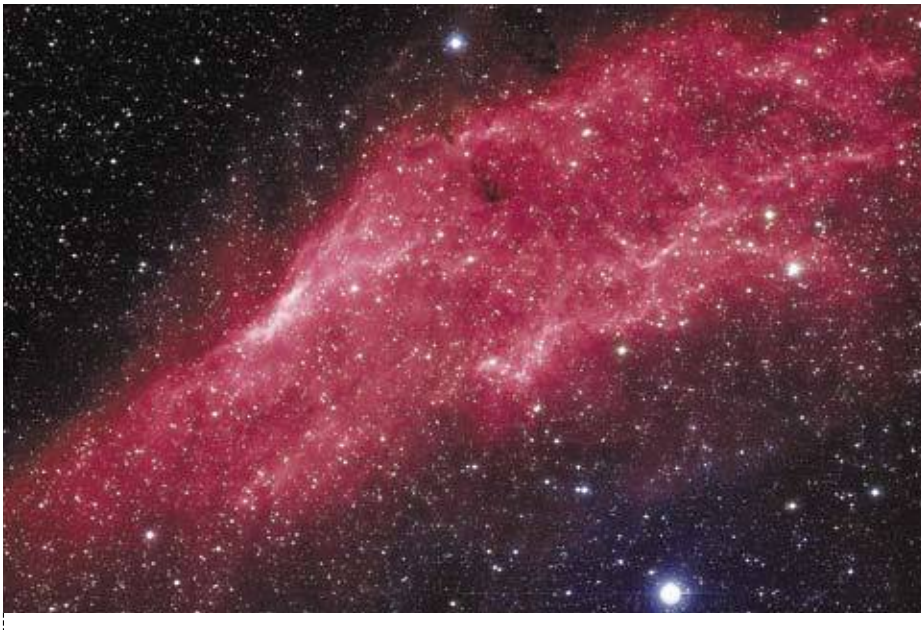
I also watch the weather patterns to see if an atmospheric pressure change will cause wind currents to degrade the seeing (the observer's term for atmospheric steadiness). Because I live near the Pacific coast, I get a marine layer overcast about half the year; so I often travel to a place where seeing should be better.

I do much of my imaging in California's Anza Borrego desert, usually while attending our local astronomy club's star parties. Our observing site in Little Blair Valley is secluded, but spacious enough so we don't step on each others' toes in the dark. Rocky hills block the light pollution near the horizon. On non-star party weekends, I sometimes head for a clear spot on a mountaintop.



THE CONE NEBULA, bottom, is a cloud of dust and cold gas blocking the light produced by the Christmas Tree Cluster (NGC 2264) that surrounds it. Note the textured Foxfur Nebula just to the upper right of the bright area near the center. Phillips took all images shown with a 4-inch Takahashi FSQ-106 apochromatic refractor at f/5.3 and an SBIG ST-10XME CCD camera.

SAGITTARIUS contains many wonderful nebulae, but few are as intricate as NGC 6559. This wide-field view shows numerous dark lanes amid the glowing hydrogen clouds.



THE CALIFORNIA NEBULA (NGC 1499) ies 1r000 light-years away in Pbrseus. When observing this nebula visually, use a Hydrogen-beta filter to bring out detail. This image is a two-pane mosaic, each having a total exposure time of 1 hour 50 minutes.

LIKE A CIRCULAR RAINBOW, the Helix Nebula (NGC 7293) in Aquarius shows many colors, but only to the sensitive detector of a CCD camera. Throu h binoculars or a telescope, the Helix appears grayish because it's not bright enough to trigger your eyes' color receptors.

Background

My first experience observing came at age 10, when I received a 3-inch reflector for Christmas. The little scope met its demise when I was setting up for a solar eclipse. I positioned the scope prior to the eclipse and had run back into the house to retrieve the safe-viewing instructions. While I was gone, the entire plastic eyepiece and holder melted into a puddle on the primary mirror. I learned a lesson that day.

I studied astronomy in college but did not acquire another telescope until the mid-1990s, when I purchased an 8-inch Dobsonian-mounted reflector. It was a fine scope, but I wanted a motor-driven mount, so I soon traded it for a 10-inch Meade LX200 Schmidt-Cassegrain telescope.

I did a lot of piggyback and prime-focus imaging with the help of focal reducers. I used film back then — Kodak Technical Pan, Fujichrome 400, and Kodak PPF, all hypersensitized in forming gas.

Over time, I developed a solid understanding of the problems associated with guiding, mirror movement, differential flexure, equipment setup and adjustment, and many other issues one encounters while learning to take astrophotos.

I decided to try digital imaging in the 1990s. I have owned five Santa Barbara Instrument Group (SBIG) CCD cameras so far. Now I use the ST-10XME.

Procedure

My setup is common among today's amateur astronomers. I took all images shown here through my 4-inch Takahashi FSQ-106. The scope sits on a bracket that also can hold a side-by-side guide camera or a piggybacked 35mm camera.

I fabricated an adapter to attach the assembly to a Takahashi EM-200 mount that sits on a Meade giant field tripod connected with another homemade adapter.

I plan all my shots with the help of *TheSky* software from Software Bisque. The program displays available guide stars, shows what's in the imaging system's field of view, controls my telescope mount, and shows where my scope is pointed — all superimposed over a virtual sky on my computer screen.

Daniel B. Phillips *resides in Oceanside, California. He's looking forward to imaging smaller celestial objects with his new 8-inch sakah shi MT-200 Newtonisn r flector.*

WHIRLING ELEGANTLY 3 million light-years from Earth, the Pinwheel Galaxy (M33) is a olorful array of blue and white stars pep pered with red star-forming clouds of hydrogen. From a dark site, sharp-eyed observers can detect M33 without optical aid.

IC 1805 is a nebulous region in Cassiopeia. Visually, this is a faint object, t not to the author'b CsD camera, which pturee great detail and lots of color. The small star cluster Melotte 15 lies at IC 1805's center (brightest area).

ABOUT 1,000 YEARS AGO, a giant stellar explosion called 9 supernova created the Jellyfish Nebula (IC 443) in Gemini. As the star's outer layers expand, they seed nearby nebulae with heavy elements, and their motion begins the process of star formation. The bright star to the right is Propus (Eta [η] Geminorum).

THE VEIL NEBULA (NGC 6992/5) is the eastern part of the vast Cygnus Loop, a supernova remnant that appears 6 times as large as the apparent diameter of the Full Moon. To observe this object, use a wide-field eyepiece fitted with an OIII filter. To see th entire loop, unlock your scope's drive and pan this area.

I use Technical Innovations' Robofocus sys em, shich is controlled by a program called *FocusMax*. Focusing tates about 30 seconds and is spot-on every time.

Diffraction Limited's *Maxim DL* is my choice for camera control and image calibrat o , and Ron Wodaski's *Bloomer* plug-in repairs bloomed (too-large) stars in the images. I expose each frame as long as possible so the resulting images have less graininess.

I align the calibrated frames with Auriga Imaging's *RegiStar*. My image data often are collected during several imaging sessions at different locations, but *RegiStar* guarantees an exact fit.

I stack the frames in *Maxim DL*. My Combine method of choice is usually Median. This removes artifacts not common to all image frames, such as airplanes, satellites, and cosmic-ray hits.

I transfer each combined color-channel image into Adobe *Photoshop*. I do not have a set process from this point on. For example, I have processed using LRGB, HαRGB, HαHαGB, RRGB, and BRGB techniques, where the first letter represents the filter used for the brightness channel in the final image, and the following letters represent the filters used for the color in the image.

I print my images on one of two Epson printers. The model 1280 provides a great glossy print, and an older 2000P works well for archival printing. Behind glass, there's almost no visual difference, but the archival prints will hold up longer.

One of the best things amateur astronomers can do is help each other by sharing information. My work has benefited from the contributions of fellow amateurs who have provided unselfishly a wealth of information. The result is on my bulletin board: images of planets, nebulae, and galaxies amid for-sale ads for Mercurys, Saturns, and Tauruses.

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We've been helping people choose the right telescope since 1979. We have the experience (a staff total of over 150 years of experience using and selling telescopes) to help *you* pick the telescope that fits your needs (and your budget) from the hundreds of telescopes we stock. And, with sur seven-figure inventory, we can usually ship you the rightöscope right away.

We started ***astronomi s*** over 25 years ago because we loved astrono y,

No-guesswork Celestron SLT go-to scopes s rt a $249

You don't need to know Polaris from the Pleiades to find your w y aro nd the sky with a **Celestron SLT** go-to telescope. With Celestron SkyAlign technology, just point your SLT at any three of the 50 brightest lights in the sky (3 stars, or 2 stars and a planet), and the SLT will find over 4,000 deep space objects for you *automatically*. A few anonymous points of light in the sky are all you need to find your way around the heavens like a pro.

Celestron SLT no-guesswork scopes are available in the following sizes:

NexStar 60, 60mm refractor **$249**00
NexStar 80, 80mm eJr **339**00
Ne S ar 102,102mm refractor **419**00
NexStar 114, 114mm reflector **379**00
NexStar 130, 130mm reflector **399**00

Each is complete with two eyepieces, a red dot finder, motor drives, stainless steel tripod, NexStar computer, software to control the scope from your home computer, and more.

Celestron 11" scopes start at only $1699.

With almost twice the light-gathering of an 8 scwpe **Celestron Advanced Series** 11" German equatorial mo nt Séhmidt—a seg ains show you more deep space wonders than an 8" SCT on a fork mount – *for about the same price.*

The 11″ Advanced Series telesco°es available from our stock inXlude:

C11S, Ger an equatorial mount **$1699**00
C11S (XLT), as above, XLT coatings **1979**00
C11S GT, go-to German equatorial **1999**00
C11S-GT (XLT), go-to, XLT coatings **2279**00

The C11S and C11S (XLT) have a heavy-duty equatorial mount, adjustable height tripod with 2" steel legs, slow motion controls, setting circles, a 40mm Plössl eyepiece, and a 9 x 50mm finder. Starbright multicoated optics are standard. State-of-the-art Starbright XLT multicoatings on the C11S (XLT) give you an extra 16% light transmission for even brighter deep space images. An optional dual-axis drive is available.

The go-to C11S-GT and C11S-GT (XLT) models have dual motor drives and a NexStar computer to automatically find and track over 45,000 stars and objects for you.

At only 29 lbs. for the heaviest component, each is easy to transport and set up. And, best of all, they are *all* very affordable. A *big* telescope no longer costs a fortune, thanks to Celestron.

No-guesswork Celestron CPC Schmidt-Cassegrains.

You don't need to know Alkaid from Algol to find your way around the sky with a **Celestron CPC**. Just point it at any three of the 50 brightest lights in the sky (3 stars, or 2 stars and a planet), and the CPC finds over 45,000 deep space objects for you at the touch of a button. You don't have to memorize a star chart to use a CPC scope. The built-in GPS system and a few anonymous points of light in the sky are all you need.

Celestron CPC Schmidt-Cassegrains are available in the following sizes:

8" **CPC800**, Starbright coatings **$1899**00
8" **CPC800X**, XLT coatings **1999**00
9¼" **CPC925**, Starbright coatings **2349**00
9¼" **CPC925X**, XLT coatings **2499**00
11" **CPC1100**, Starbright coatings **2599**00
11" **CPC110 X**, XLT coatings **2799**00

Each has all the visual and ph tographic features you want and need, plus Celestron's best multicoated optics ever.

Celestron snaps the solar system for $99.

There's a real color CCD camera in the **Celestron NexImage** Solar System Imager. It's a Sony HAD (Hole Accumulation Diode) full color CCD with 640 x 480 5.4 micron pixels.

The NexImage takes high power Moon and planet images with any scope and sends them to your computer to view live or print out later.

PREMIER SELECT CELESTRON DEALER

The NexImage Reducer Lens, our #8320 at $24.50, doubles the NexImage field of view for wider lunar panoramas. Also available is the 1.25" NexImage UV/IR filter for sharper planetary surface detail with all CCD cameras. It's our #37CIR at $57.95.

Are these great alues? You bet they are.

The low prices of these **Konus** telescopes are downright amazing.

Consider the 90mm **Konusmotor-90** f/11 refractor, to the left. It has a good quality equatorial utt, *two* 1.2 " Pl s l eyepieces, a battery-powered motor drive – and it's value-pöi e at only $209!

The **Konusky-200** " f/5 reflector, right, has a heavy duty equatorial mount wwth steel leg tripod,*dual-a is* DC drives, *two* good 1.25" Plö sl eye-pieces, an 8 x 50mm finderscope, a polar axis finder – and it's value-priced at only $519!

The **Motormax-150** 6" Maksutov, right, has the same h avy duty mount and a cessories as the 8 reflector. It't val e-priced at a low $799, wel° b low the price of other large Maks.

A binoviewer *with* eyepieces for only $199.

Other binocular viewers can cost over $1200 without eyepieces, but a **Burgess Optical** Binoviewer costs only $199, *including* two eyepieces. Observing with two eyes through the Binoviewer's 22mm clear aperture multicoated BaK-4 prisms shows you up to 40% more detail than you can see through a single eyepiece.

Designing a binoviewer isn't rocket science, and modern computerized manufacturing makes this one both good *and* inexpensive. We've sold over 400 of these to very happy buyers. Try one and see the 40% *you've* been missing.

Wide angle eyepieces for only $49. Four for $149 . . .

Burgess Optical 1.25" Wide Angle eyepieces are good performers at a remarkably low price. Their very sensible $49 price makes them an obvious choice for binocular viewers. Available in a 60° field 8mm or 12mm, a 65° field 17mm, and a 67° field 20mm.

A set of all four costs only $149. It's like buying three and getting one free!

. . . and 70° super wide angles start at only $59.

Burgess Optical 1.25" and 2" Super Wide Angle eyepieces have a huge 70° field but cost much less than big-name eyepieces. By not spending money on expensive advertising, Burgess keeps the quality high and the price low.

A 74° 9mm and 72° 16mm and 20mm 1.25" Ultra Wides are only $59 each. The 2" 70° models include a 26mm and 32mm at $79 each and a 38mm at only $89.

A set of all six costs only $299. It's like buying four and getting two free!

I have received my Meade 10" LX200 telescope. You should be commended for your good service. I found your salespeople and technical help to be exemplary. Thanks for the professional handling of my requests. Most companies seem to have lost that today. Thanks!!

Customer Quote of the Month #162

A Telegizmos helps your scope keep its cool.

A **Telegizmos** scope cover protects your scope from the sun and dew at star parties and in your backyard. Developed for NASA as a spacecraft insulator, this aluminized multilayer cover is strong, light, tear/puncture resistant, and much more durable than Mylar.

Prices start at $29 for an ETX cover. An 8" SCT cover costs $49. Even the cover for an 18" truss tube Dob costs only $68.

The Telegizmos cover for a 4" refractor

Want to rea *unbiased* equipment reviews by astronomers just like you? Find them www.cloudnights.com

A William Optics Petzval-type semi-apo for $448.

Another manufacturer's 4" Petzval-type apo optical tube costs $3600 and is worth it. The **William Optics ZenithStar 66 Astro Version** has 66mm multicoated Petzval 4-element optics with an ED glass element for nearly color-free performance. It costs only $448 and is *more* than worth it.

It comes with a rotatable 2" Crayford focuser, 1/10th wave accuracy 2" star diagonal with 99% reflectivity *dielectric* mirror, 1.25" adapter, retractable lens shade, dust caps, and a soft carry case.

Its removable L-shaped mounting shoe fits a photo tripod or SCT piggyback. It makes a super finder for your main telescope and an optically outstanding second scope for travel, nature study, and spur-of-the-moment astronomy.

Here's a bird in the hand worth having . . .

The 9, 15, and 20mm 1.25" Swan eyepieces from **William Optics** all have a very wide 72° field of view, with sharp images all the way across the field. Best of all, each 1.25" Swan costs only $78.

Equally sharp are the big 25, 33, and 40mm 2" Swans at only $118 each. They also have a wide 72° field (70° on the 40mm).

A 2" *quartz* dielectric diagonal for only $298.

The new **William Optics** 2" star diagonal has a premium 1/10th wave accuracy ultra-stable *quartz* first surface mirror instead of glass. And instead of 97% reflectivity enhanced aluminum coatings, it has durable 30-layer *dielectric* coatings for a full 99% reflectivity. It's our part #W2DQ, and it's priced at only **$298**. There's also a version that threads directly onto a Schmidt-Cassegrain rear cell (our part #W2DQSCT) for only $318.

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not just as a business. Our sales may have grown over a thousand-fold since that first year, but we're still the same family-ownpd, ffmily-run, full-line telescope dealer we were in 1979. And we still love astronomy.

astronomics. No hard sell. No guesswork. Jkst honest advice, t e time to make sure you get the right telescope and accessories, and a good price. Call us toll free at (800) 422-7876 and find out for yourself.

We stock lots of TeleVue. Does your dealer?

NP-101 **$3595**

Others may *say* they carry TeleVue, *but we actually keep TeleVue scopes and accessories in stock.* Lots of them.

A few of the TeleVue scopes we have in stock for immediate shipment are listed below. These are basic optical tubes only, with dust covers and a carry case, for use with your own accessories.

Complete packages (for use on your own mount) with a star diagonal, Plössl eyepiece, mounting ring, dust covers, and carry case, are also in stock.

TV-60, 2.4" f/6 apo **$795**00
TV-76, 3" f/6.3 apo **1275**00
TV-85, 3.35" f/7 apo **1680**00
TV-102, 4" f/8.6 apo **220** 00

New lower prices on TeleVue light pollution filters.

$95

The high-performance **TeleVue** d electric narrow-band light pollution filters have dropped in price, but you still get the same outst/ndin/ image-/mproving performance.

heir special red blocking technology and ground and polished optical quality BK-7 substrates allow brighter, sharper star images without the red fringing seen on most light pollution filters.

Th UHC-type narrow band filter is good for all nebula types and instrument sizes.

The Ox/gen III lineband filter gives you enhanced performance on planetary nebulas with larger telescopes.

UHC, for 1.25" eyepieces **$95**00
UXC, for 2" eyepieces **185**00
Oxygen III, for 1.25" eyepieces **95**00
Oxygen III, for 2" eyepieces **85**00

Dioptrx lenses eliminate eyeglasses for observing.

$98

TeleVue Dioptrx astigmatism-correcting accessory lenses attach to the top of TeleVue eyepieces so you don't have to put up with the inconvenience of eyeglasses when you observe. They are available in 0.25 diopter steps from 0.25 to 2.5 diopters.

They work with these TeleVue eyepieces only: 26mm and 31mm Nagler type 5; 22mm, 27mm, 35mm, and 41mm Panoptic; 22mm, 40mm, nd 55mm Plössl; all Nagler type 4; and all Radians.

Each TeleVue Dioptrx lens is made of multicoated precision-ground optical glass, mounted in an anodize aluminum housing that locks into place on your TeleVue eyepiece.

The most popular telescope website . . .

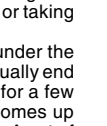
Numbers don't lie! As of June, 1, according to the leading independent internet rating service, **www.astronomics.com** was still the most visited telescope store on the web (for what seems like the umpteenth month in a row).

astronomics.com visits were even ranked ahead of the major telescope manufacturers' sites.

Try **astronomics.com** and see why more people visit our site for the right information, the right products, and the right prices.

The right accesso ies make your observing easier.

A red flashlight protects your dark-adapted night vision while you observe. **Celestron's** variable brightness red flashlight, our part #VLED, costs **$21.95**.



The **Rigel Systems** variable brightness red light shown, our part #4591, is **$24.95**.

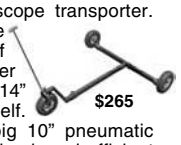
Rigel's 2-color variable brightness light (#4592) – red for reading star charts, blue-white for setting up or taking down your scope – is **$29.95**.

Vibration suppression pads under the legs of your telescope tripod virtually end the tremors that blur your view for a few seconds every time a breeze comes up or you touch the scope to focus. A set of three **Celestron** anti-vibration pads, our part #VSP, costs **$49.50.** The **Meade** #895 pads to the right cost **$49.95.** Both sets take the frustration out of observing and are well worth their low cost.

Celestron Power Tank rechargeable 12-volt batteries have the power you need to run your telescope and accessories all night long. You can recharge them hundreds of times, saving you big bucks over the cost of buying new flashlight batteries every few weeks. Each has *two* 12V DC cigarette lighter outputs; 3, 6, and 9V DC outputs for accessories; an emergency spotlight; a built-in recharger; shoulder strap; carry handle; and more. The 7 amp hour Power Tank shown, our part #4512V, is only **$59.95**. The 17 amp hour Power Tank, our #4517V, is only **$89.95**.

Antares 7 x 50mm and 12 x 80mm right angle finders cost from **$79.95** to **$184.95**. You can choose from Celestron black, Meade blue, or gloss white in either standard mirror-image or erect right-reading models that show you the sky the way it appears on star charts.

You'll end the drudgery of taking out your scope one piece at a time with the **$265 Scopebuggy** scope transporter. It's so efficient that the 6 year-old daughter of one customer moves her Dad's fully-assembled 14" Celestron all by herself. The Scopebuggy's big 10" pneumatic tires, pivoting front wheel, and efficient pull handle make it child's play to move a telescope weighing up to 300 lbs.


$265

We ship Meade from *our* stock to save you time/money.

M°awtu8" LX200 GPS **$2299** *fr ight paid*

A lot o Meade dealers don't stock Meade telescopes. They have Meade ship them to you. That means you pay sales tax if you live in California" A Californ a resident doesn't pay sawes tax on a 7-10" LX200 or RCX400 shipped from our stock.

And, if a dealer has to order a scope from the factory, it may take days before he can even find out if it's in stock at Meade. We tell you immediately if we have a scope for you, and you won't have to wait days for the factory to s ip.

Plus, if you live in the midwest or on the east coast, it often takes an order two to four d ys/ longer t arrive when it's shipped from a west coas warehouse than it does when it's shipped from our warehouse in the center of the country.

Here are the *freight-paid* prices for the LX200/RCX400 scopes that we typi ally sn p from our inventory via Fedex ground to the 48 states to save you time and money:

7" LX200 Maksutov **$2799**00
7" LX200 Maksutov, w/gHTC ..... x...**2949**00
8" LX200 midt..... **2299**00
8" LX200 Schmidt, w/UH C..... **2474**00
10" LX200 Schmidt **2999**00
10" LX200 Schmidt, w/UHTC **3234**00
10" RCX400 Ritchey-Chrétien, UHTC .x **5149**00

We're your Meade Tier 1 stocking dealer . . . get accessories last om www.astronomics.com/meade.

Being a Meade Tier 1 stocking dealer means we keep most Meade scopes and accessories in stoc in our own seven-figure inventory. You don't have to wait days for your local dealer to have Meade sh/p a scope or accessory to you. In many cases, we ship from our stock, usually saving you time and money – and in most cases saving you the sales tax. Visit our website for fast shipping.

Meade Deep Sky Imager ro, $499.

The **Meade Deep Sky Imager Pro** takes monochrome astronomical photos for only $399 – a fraction the cost of a CCD camera. uy the camera/color filter package shown at $499 and it takes tri-color images as well. Works with any telescope, but you can use its NASA-developed "Drizzle" software with Meade Autostar-equipped ETX, LX90, LX200, or RCX400 scopes to take images *up to 4.9 megapixels in size.*

Meade LX90-LNT – new 8", 10", and 12" scopes.

The best-selling **Meade LX90-LNT** 8" has been joined by 10" and 12" models. The 8" and 10" scopes ship from our stock, so we save you shipping time over dealers who must have them drop-shipped from Meade (and if you're in California, we save you the sales tax).

Here are the *freight-paid* prices on the LX90's shipped from our stock:

8" LX90-LNT **$1799**00
8" LX90-LNT, w/UHTC **1974**00
10" LX90-LNT **2299**00
10" LX90-LmT, w/UHTC **2474**00

For 12" LX90's shipped from Meade:

12" LX90-LNT **$2999**00
12" LX90-LNT, w/UHTC **3294**00

Level North Technology makes it easier to line up your scope on the sky. Simply tell an LX90-LNT your location *or zip code.* It levels its optical tube by itself, aims it north, and moves to its alignme t stars – *automatically!* Center the red dot finder on the alignment stars (you get an 8 x 50mm finder, too), and start enjoying go-to computerized observing. The LX90 is an *easy* scope to use, and now it comes in large economy sizes!

Meade 8" LX90-LNT **$1799** *freight paid*

Meade accessory pack ges save you a third.

Meade has combined popular ETX, LXD75, LX90, LX200, and RCX400 accessories into packages that cost a third less than buying the items separately.

Five ETX kits for terrestrial and astro no o l obse ing and astrophotogra phy start at $99. Three LXD75 kits for observing /nd astrophotography start at $199. An LX90 astrophotography kit is $249. And two LX200/RCX400 kits for astrophotography start at $349.

Full details on the contents of the kits and the big bucks you save on each are at **www.astronomics.com/meade**.

We ship Meade RCX scopes from our stock.

The **Meade** modified Ritchey-Chrétien s opes p qavi ally the same optical design as the Hubble Space Telescope into affordable and portable scopes for a a-teur astronomers. The 10" and 12" scopes often ship from our stock, so we save you time over dealers who have them drop-shipped rom Meade (and it you're in California, we save you the sales tax).

The 10" **RCX400 10"**, frt paid **$5149**00
The 12" **RCX400 12"**, frt eid..... **6799**00
The 14" **RCX400 14"**, frt paid **9299**00
3he 16" **RCX400 16"**, frt paid ... **16,399**00

Level North Technology and GPS make aligning on the sky *automatic.* You start observing in minutes. Standard equipment UHTC optics for 15% higher light transmission, High Precision Pointing, Permanent Periodic Error Correction, a 2" UHTC star diagonal, and a 2" 24mm Ultra Wide eyepiece – the list of f a-t res just goes on an on.

Meade 12" f/8 RCX400 Ritchey-Chrétien **$6799** *reight paid*

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Our multiple award-winning Internet address: www.astronomics.com

PHONE HOURS: 8 to 9 CST Monday thru Friday, Saturday 12 to 5. STORE HOURS: 9 to 5 Monday thru Friday, Saturday by appointment.

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Price match fine print: competitor's price must be verifiable and available nationally; chain store, close-out, and going-out-of-business prices are excluded; no retro ctive price matching; a package price must be from a single competitor.

Telescopes from the golden age of observing still provide great images.

/// BY MIKE REYNOLDS

Explore the sky with classic glass

"Wow — what a view!" exclaimed a young man looking at the Moon through my telescope. "What type of telescope did you say this is?" he asked. "An Alvan Clark 8-inch refractor that was built in 1883," I responded. His reply was as classic as the telescope:

"I didn't know old stuff could produce such screamin' views."

Welcome to the universe of antique telescopes. Many observers have discovered — or rediscovered — that old scopes can provide views that parallel (and some say exceed) comparable modern telescopes. Others look at antique telescopes as precious works of art — wonderful optics mounted in a tube, crafted with care, and placed on a still-functional mount.

ALLEGHENY OBSERVATORY

THE 30-INCH THAW REFRACTOR at Allegheny Observatory in Pittsburgh contains the largest lens made by the firm of John A. Brashear.

The most familiar of the 19th- and early 20th-century telescope-makers are Alvan Clark & Sons and John Brashear. These two firms, especially Clark, were known for their big refractors in the 19th century. Clark was responsible for the two largest refractors in the world: the 40-inch Yerkes refractor located in Williams Bay, Wisconsin; and its slightly smaller sibling, the 36-inch Lick refractor on Mount Hamilton in northern California.

A handful of 19th-century optical shops turned out high-quality telescopes and accessories, prized at the time by well-to-do amateur astronomers, colleges, private research observatories, and even the U.S. government. Some of these larger instruments still are available for public viewing at facilities like Chabot Space & Science Center in Oakland, California (20-inch Brashear refractor and 8-inch Clark refractor), the University of Denver's Chamberlin Observatory (20-inch Clark-Saegmuller refractor), and the Roper Mountain Science Center in Greenville, South Carolina (23-inch Clark refractor). Even research facilities like Lowell Observatory in Flagstaff, Arizona (24-inch Clark refractor), hold regular public viewing nights.

None of the famous telescope-makers was born an optician. Each worked in an unrelated field before achieving fame.

LICK OBSERVATORY

THE GREAT 36-INCH REFRACTOR at Lick Observatory on Mt. Hamilton, California, attained fame in 1895, when Edward Emerson Barnard visually discovered Amalthea, the fifth moon of Jupiter and the last solar system satellite found visually. The lens for this great instrument — the second-largest refractor — was made by Alvan Clark & Sons.

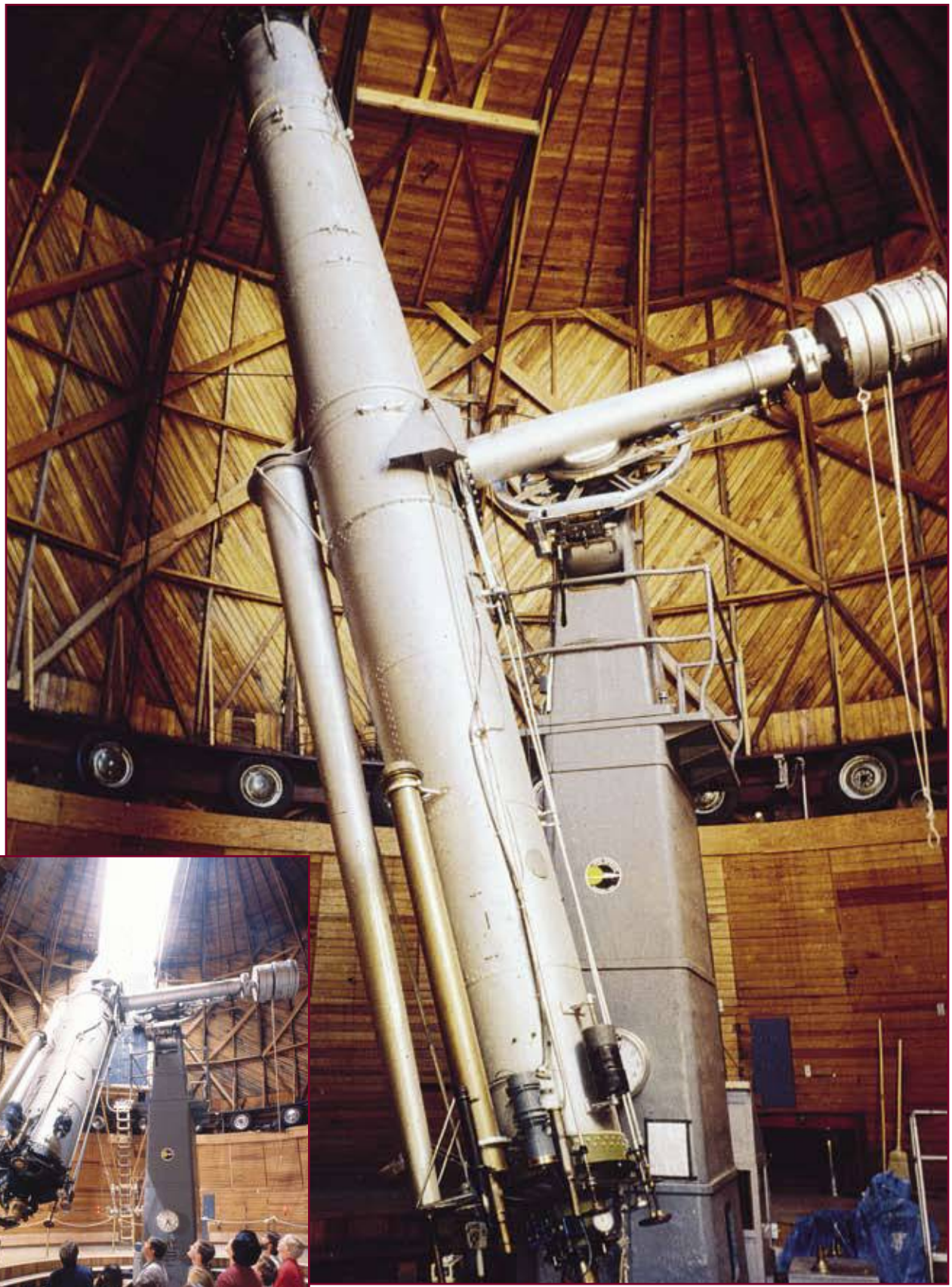
CARTER ROBERTS

DEDICATED IN 1885, the 26-inch Alvan Clark & Sons refractor at the Leander McCormick Observatory, University of Virginia, provides great views to visitors on the first and third Fridays of each month (weather permitting).

Family legacy

Alvan Clark was a portrait painter and engraver. At 40, he became interested in optics because of the Great Comet of 1843's appearance. His son, George Bassett Clark, began construction of a telescope much like Sir Isaac Newton's early reflector while studying at Phillips Academy.

The younger Clark soon involved the father in his project, and this collaboration eventually led to the founding of Alvan



BOTH PHOTOS: LOWELL OBSERVATORY

THE 24-INCH CLARK REFRACTOR at Lowell Observatory in Flagstaff, Arizona, was the instrument Percival Lowell used to build a case for life on Mars. Lowell purchased the telescope in 1896 for $20,000. *Left*: **Visitors still peer at Mars and other celestial wonders during the many public observing nights at Lowell.**

DUANE JAEKES

THIS 3-INCH BRASHEAR refractor sits atop a W & E Gurley tripod. Brashear standardized eyepiece-barrel diameters to 1¼", which is still used today.

ALLEGHENY OBSERVATORY ARCHIVES

THE 30-INCH LENS of Allegheny Observatory's Thaw Memorial Telescope sits on the workbench in the Brashear shop prior to delivery in 1914.

CARTER ROBERTS

THIS 6-INCH CLARK refractor rides on a Saegmueller mount under a roll-off observatory at the Leander McCormick Observatory, University of Virginia.

Clark & Sons in Cambridgeport, Massachusetts. George's brother, Alvan Graham Clark, also joined the firm. Alvan and Alvan Graham had incredible talent for making fine optics; George concentrated on the telescopes' mechanical aspects.

The Clarks tested their optics on double stars. Many double star discoveries — including Sirius B, the first white dwarf star — are credited to them.

The senior Clark also made adjustments under the stars. When he took a lens out for star testing, he'd defocus the image to check for errors, place some optical polishing rouge on his thumb, feel the error on the lens, and polish out the defect until the surface was perfect.

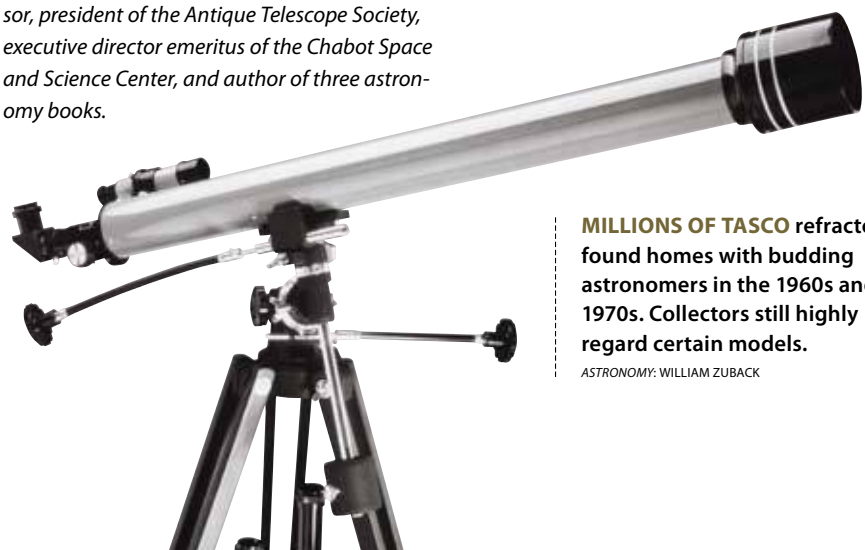
Mike Reynolds *is a college astronomy professor, president of the Antique Telescope Society, executive director emeritus of the Chabot Space and Science Center, and author of three astronomy books.*

Alvan Clark & Sons represents the pinnacle of 19th-century telescope-making, but it wasn't alone. One firm in particular did almost as well.

From steel to stars

John Brashear's interest in astronomy was sparked as a child, when his grandfather took him to look through a friend's telescope. Although he was interested in astronomy, his lack of education and social status dictated taking a job in the Pittsburgh steel mills. Soon, people recognized Brashear's mechanical talent, which extended to his love of astronomy.

His first telescope, a 5-inch refractor, took 5 years to complete; the first objective cracked soon after he completed it. Yet



MILLIONS OF TASCO refractors found homes with budding astronomers in the 1960s and 1970s. Collectors still highly regard certain models.

ASTRONOMY: WILLIAM ZUBACK

/// OLD SCOPE CONNECTION

The Antique Telescope Society (ATS) was founded in 1992 by Bart Fried, a Brashear expert. Fried had talked with a number of fellow antique-telescope enthusiasts, who encouraged the formation of such a group. The ATS meets in the fall each year at different historic sites. Some sites have included the U.S. Naval Observatory (its first meeting), Yerkes Observatory, Mt. Wilson and Palomar Observatories, and Lick Observatory.

Meetings also have been held in England and Ireland, where ATS members visited "The Leviathan of Parsonstown" at Lord Rosse's Observatory at Birr Castle. At many of its meetings, Society members are treated to rare behind-the-scenes tours, opportunities to inspect telescopic giants, and occasionally, a chance to observe through historic telescopes. — *M. R.*

Contact The Antique Telescope Society:
Walter Breyer
Executive Secretary
1878 Robinson Road
Dahlonega, GA 30533
[e] whbreyer@syclone.net
[w] webari.com/oldscope

GREGORY L. GONIA

THE "BRASS ROW" impressed all who saw it at the Antique Telescope Society's 1993 meeting. In the foreground is a 2-inch Troughton & Simms refractor. Behind it sit 6-inch (left) and 4-inch Alvan Clark refractors.

Brashear went on not only to make a second objective, but, like the Clarks, some of the finest refractors in the world.

When Brashear developed a mirror-silvering technique, he bought an ad selling "silvered-glass specula, diagonals, and eyepieces made for amateurs desiring to construct their own telescopes." Orders flooded in, and Brashear became an optician.

To Brashear's credit are many fine small telescopes and several large ones, such as the Dominion Astrophysical Observatory's 72-inch mirror in Victoria, British Columbia; Allegheny Observatory's 30-inch Thaw photographic refractor and 30-inch Keeler Memorial reflector in Pittsburgh; and the University of Michigan's 37-inch mirror.

Brashear contributed to standardization by making all of his eyepiece barrels with an outside diameter of 1¼". Other manufacturers adopted this measurement and still produce such eyepieces.

As is the case today, several large telescope-makers dominated the market. The need was great, however, so smaller manufacturers also sold lots of scopes.

Other early telescope-makers not well known included Bardou, Browning, Dollond, Fauth, Fitz, Mogey, Petididier, Porter, Tully, and Zeiss. It's fortunate so many telescopes were sold back then. It increases your chances of acquiring one today and lowers the price of available models.

Your piece of history

Individuals shopping for smaller antique instruments seek antiquity, history, value, and excellent viewing. Antiques in the 3- to 6-inch range can be expensive and often need restoration work.

Some owners enjoy restoring an antique telescope to its former glory. However, refurbishing an old scope isn't as easy as removing old lacquer or polishing brass. Some collectors, in their haste or lack of knowledge, not only devalue antique telescopes but damage them beyond repair.

If you want an antique telescope, be prepared for sticker shock. Even well-worn or battered telescopes can be expensive.

In years past, auctions were popular. More often today, old scopes turn up on eBay, AstroMart, or via a network of antique enthusiasts that form the Antique Telescope Society (see "Old scope connection" on page 86).

Determining if the instrument is what the seller claims can be tricky. Watch out for modern — or even antique — copies. I've seen a couple of "Dolland" (instead of Dollond) telescopes on the market. You have to figure the maker at least knew how to spell his own name!

Ask several questions before you buy: Are you buying from a reputable dealer or a well-known collector? What is the condition of the instrument? Are the optics original? Are they in good shape? Are included eyepieces original?

The best way to avoid a purchasing mistake is to look at many old scopes. Look for the quality of details like the amount of wear on focus-knob knurling, the detail of the tripod-leg wood, and the way the lens cell is assembled.

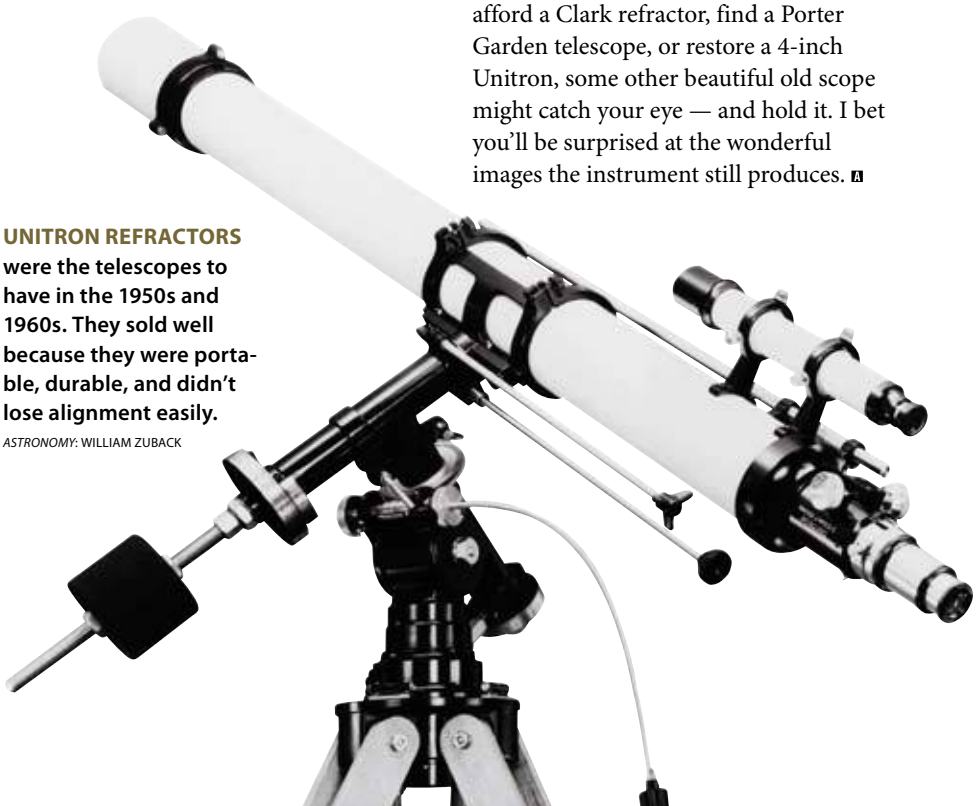
Talk to people: museum staff, antique restorers, other collectors, and members of the Antique Telescope Society. Such individuals often are willing to share their expertise and love of old scopes.

Although you might not be able to afford a Clark refractor, find a Porter Garden telescope, or restore a 4-inch Unitron, some other beautiful old scope might catch your eye — and hold it. I bet you'll be surprised at the wonderful images the instrument still produces.

/// HISTORY DOWN THE TUBES

Not all is well in the arena of antique instruments, even though the Antique Telescope Society and other groups strive to preserve their history. Stories appear frequently about universities that decide "old is no longer good."

Often they dismantle their instruments, then store them where parts disappear off of the telescopes and mounts. Or worse, institutions, because they don't want to go through the "hassles" of selling or donating their telescopes, simply will throw them away or allow buildings — along with telescopes — to meet their fate with the bulldozer! And it is not uncommon to hear of a university that throws "those old astronomy books" into the dumpster. — *M. R.*



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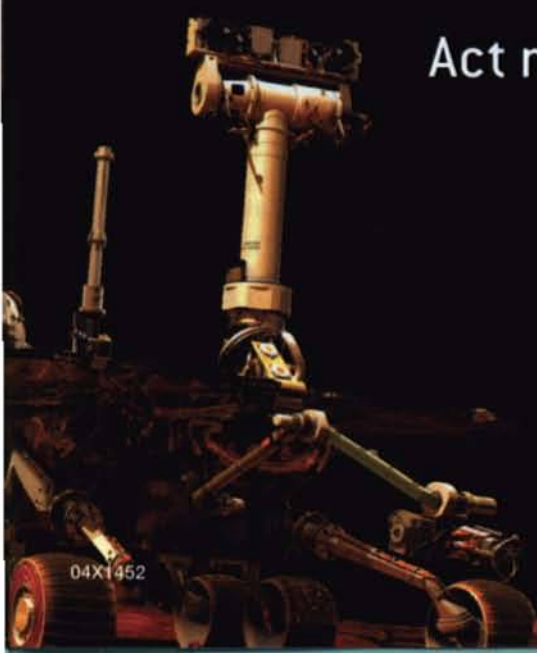

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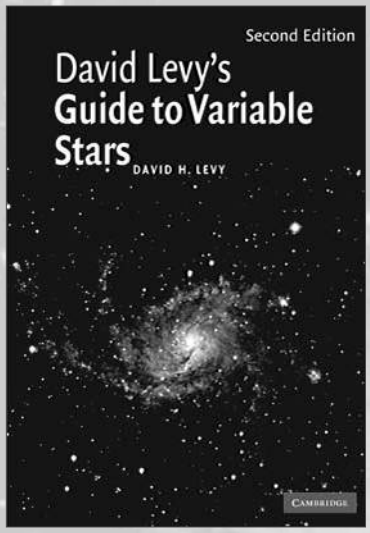

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Cosmology for everyo e

Evolving Cosmos

Govert Schilling, 136 pages, Cambridge University Press, 2004; hardcover, $40

Pity the poor cosmology writer. Planetary science offers lofty volcanoes, yawning hasms, and immense storms whirling through alien skies. And stellar and galactic astronomy, while ranging far from the solar system, also serie up beautiful objects.

But cosmology? It's everywhere and nowhere. It's elusively, relentlessly abstract.

This doesn't stop Dutch science w iter Govert Schilling. As ably translated by Thomas Wray, Schilling takes his reader on a well-told and imaginative omr of the universe, starting with the Big Bang. Or, to be precise, 10^{-43} second after the Bang.

His 10 chapters echo the metaphor of co mic birth n change using single-word titles such as *Creation*, *Growth*, and *Recycling*. Each chapte present part o the story of the universe's formation and development.

The first chapter carries the reader up to the point where matter and radiation separate and t e universe becomes tofnsparent. The second chapter closes as the first stars are exploding as supernovae; as Schilling says, "The first stellar explosion also marks the start of cosmic environmental pollution, the beginning of a cosmic cycle that will one day lead to people of flesh and blood."

Schilling's style is consistently evocative yet remains grounded in science. His de- scr p on of t e o mic microwave back- ground radiation shows this: "What began as a blinding blanket of visible light has been diluted to a barely perceptible noise — a soft whisper at radio wavelengths."

The universe's story continues with the formation of galaxies and"thei mergers into clusters. Then comes star-birth and recycling, where the elements cooked in the hearts of massive sta s are blown out nto the cosmos again to re-gather into later generations of stars.

Chapter 6 introduces planets and selar systems, which are shaped through collisions, impacts, and internal forces, as d scribed in cha er 7. Lif ppears, and, after a long, crooked pathway, it spawns humans, curious about the cosmos.

But neit er the universe, nor Schilling, is yet finished. Chapter 9 takes the reader into the Sun's future. When the chapter closes, Earth has become a cinder, the Sun is a white dwarf, and humanity must find a new ho . But, he says, "It is 20 billion years after the Big Bang. The universe is still young."

The final chapter — *Completion* — loiks at what awaits the universe itself, as galaxies recede, stars age and flicker out, and matter itself evolves. Schilling outlines possible fates awaiting the universe: endless expansion, a creeping stasis, or a collapse back to a singularity with which it began.

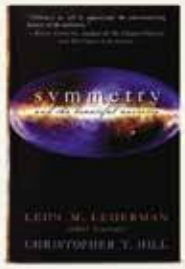
Since cosmology is, after all, the study of everything, Schilling uses pictures of stars, galaxies, nebulae, and planet . In the end, the image-bereft cosmology writer offers a gorgeous visual feast.

I noticed an important omission, however. There's little ntion of damk energy, the mysterious, repelling something that amounts to about 70 percent of the universe and is driving an accelerating expansion. But its existence is as well-established as anything in cosm log , and it stands to have a command- ing say in the universe's future.

This book is aimed at anyone interested in an overview of current cosmology (keeping in mind the caution mentioned just now), using no mathematics.

Second, this is a good book to consider giving to any imaginative young person who enjoys having his or her thoeghts d rected down new paths. One thing you can say about astronomy is it expands your horizons.

And sometimes the most exciting horizons are those that lie farthes from us. — **Robert Burnham** *is a senior editor of* Astronomy.



Symmetry and the Beautiful Universe

Leon M. Lederman and Christopher T. Hill, 365 pages, Prometheus Books, 2004; hardcover, $29.

Lederman and Hill introduce the concept of symmetry and its applica- tions to particle physics, quantum mechanics, astronomy, and, of course, th intersectnon of these fields. This book is aimed at a general audience and has many easy-to-understand diagrams to illustrate the abstract ideas.

Deep Space — Th NASA Mission Reports

Robert Godwin and Steve Whitfield, editors, 432 pages, C. G. Publishing, Inc., 2005; paperback, $34.95.

An space buff will enjoy this collection of reports — from the Pi netr missions to Cassini and beyond. Godwin and Whitfield include press kits, ission tracms, and instrum nt di grams for over 30 years of NASA missions. For what wou dn't fit in the 432 pages, a DVD is included.

Astrophysics of Life

Mario Livio, Neill Reid, and William Sparks, editors, 110 pages, Cambridge University Press, 2005; hardcover, $100.

For those interested in astrobiology, this collection of papers from the 2002 Space Telescope Science Institute Symposium allows yoo to dive to the field's recent findings and theories. It's not too mtth-heav , so most readers can follow along.

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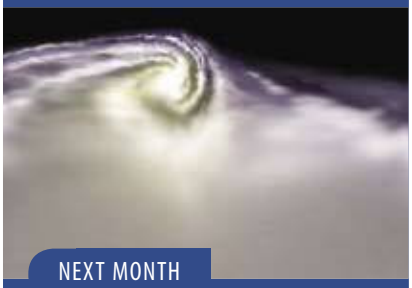

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SEPTEMBER 1–4, 2005

Located about an hour's drive from

Prineville in the Ochoco National Forest, the Oregon Star Party (OSP) brings together a great medley of hobbyists, some with large homemade instruments that use sophisticated tracking systems, and those who prefer observing with smaller scopes, binoculars, or their unaided eyes.

DAVID HAWORTH

SUNSET CLOUDS during the 2004 OSP provided a gorgeous, yet unwelcome, view for attendees. The cover eventually dispersed, allowing observers to patrol the sky.

This gathering began in 1988 with a dozen Portland-area observers assembled near the peak of Steens Mountain.

The clear, dark sky isn't the only attractive feature of the OSP. Nature lovers camp among the ponderosa, juniper, sage, and wildlife of the region and observe on the side.

For more information, e-mail ospinfo@patch.com; www.oregonstarparty.org. Also, read our article "The Oregon Star Party" (September 2004) for a recap of the 2003 gathering.

SEPTEMBER 1–5
Ark-La-Tex Star Party

Near Nashville, Arkansas. Hosted by the Red River Astronomy Club, the star party will feature great observing under a dark sky, a swap meet, door prizes, and lectures. The site offers electric hookups and showers. For more information, visit www.rrac.org.

SEPTEMBER 1–5
ICStars Star Party

ICStars Ranch, Warrensburg, Missouri. Extended through Monday, September 5, because of Labor Day weekend, this star party will feature many activities for children, including hay rides and a fossil hunt. *Astronomy* Editor David Eicher will be the featured speaker. For more information, visit icstars.com/index.html.

SEPTEMBER 1–4
Iowa Star Party

Garst Farm Resort, Coon Rapids, Iowa. Attendees can choose from accommodations ranging from tents to suites in the bed-and-breakfast. For more information, visit www.iowastarparty.com.

SEPTEMBER 8–10
Astrofest

Vana's Farm, near Kankakee, Illinois. This

26th annual gathering is sponsored by the Chicago Astronomical Society. *Astronomy* staff members will attend this star party. For more information, call Walter Glogowski at 847.910.2878; e-mail, casdarksky@ameritech.net; web site, www.chicagoastro.org.

SEPTEMBER 29–OCTOBER 2

Autumn Equinox Sky Camp

Kelling Heath Holiday Village, North Norfolk, England. This is southeast England's darkest site and is easily accessible from London and the Midlands. Besides skygazing, this event will feature lectures on a variety of topics, including meteorites, lunar observing, and getting the most from your telescope. For more information, visit www.starparty.org.

SEPTEMBER 29–OCTOBER 2

CalStar

Lake San Antonio Park, near King City, California. The site is centrally located for the convenience of San Francisco and Los Angeles-based skygazers. For more information, visit www.sjaa.net/calstar2005.html.

SEPTEMBER 29–OCTOBER 2

Lowell Star Party

Lowell Observatory, Flagstaff, Arizona. This event will feature Mars viewing through the historic Clark Telescope and a new dark-sky site on Observatory Mesa. Also scheduled are talks by astronomers, research telescope tours, and an astronomy marketplace. For more information, visit kraken.lowell.edu/lsp3/index.html.

SEPTEMBER 29–OCTOBER 2

Stella-Della-Valley Starfest

Camp Onas, near Ottsville, Pennsylvania. This gathering will feature observing, workshops, guest speakers, food service, a swap meet, and vendors. For more information, visit www.bma2.org.

SEPTEMBER 29–OCTOBER 2

Prairie Skies Star Party

Camp Shaw-Waw-Nas-See, near Kankakee, Illinois. The camp's rustic nature and the friendly atmosphere will make for a memorable star party. *Astronomy* staff members will attend this event. For more information, visit www.prairieskies.org.

SEPTEMBER 30–OCTOBER 1

All Arizona Star Party

Farnsworth Ranch, Arizona City, Arizona. Located between Tucson and Phoenix, this site will not be strongly affected by light pollution from these areas. The dominant flora is creosote bushes, so the horizon will be very low. For more information, visit eastvalleyastronomy.org/aasp.htm.

SEPTEMBER 30–OCTOBER 1

Cathedral Gorge Star Party and Campout

Cathedral Gorge State Park Campground, Panaca, Nevada. This northern Nevada location won't be affected by the bright lights of Las Vegas' casinos. In addition to stargazing, other attractions include fishing, hiking, and tours of a nearby mining ghost town. For more information, visit, www.astronomyvegas.com.

SEPTEMBER 30–OCTOBER 1

Hidden Hollow Star Party

Warren Rupp Observatory, Mansfield, Ohio. This observatory is home to a 31-inch reflector. Sponsored by the Richland Astronomical Society, this star party will feature observing, workshops, and lectures. For more information, visit www.wro.org/hiddenhollow2005.htm.

SEPTEMBER 30

Star Track: the Nightly Path of Constellations

Jeffers Petroglyphs Historic Site, Comfrey, Minnesota. This night will feature observing, a sky tour, and various cultures' folklore about the stars. For more information, visit www.jefferspetroglyphs.com. ▲

CONTACT INFORMATION

Please submit club announcements 4 months in advance to Coming Events, *Astronomy*, P. O. Box 1612, Waukesha, WI 53187, or jmcgovern@astronomy.com. Also use this e-mail address to submit your events for our online calendar.

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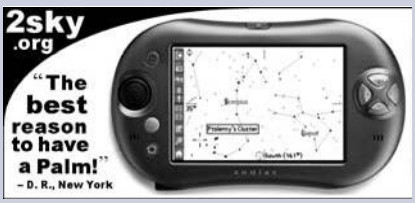

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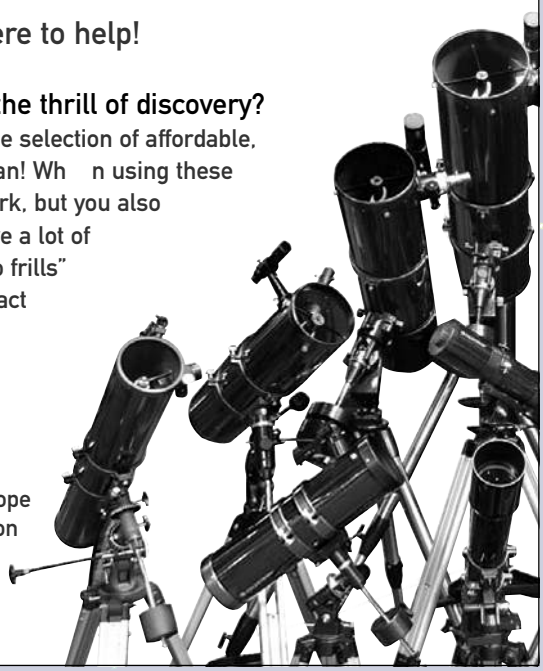
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As we peer into the sky with larger telesco es and more sens ive detect s we sN m see sine e ialaxies anym re. S m syst ms se le the Milky Way, which has two small gala ies reholvin ar end it the Large and Small Magellanic Clouds. Occ sio ally, we observe two colliding galaxies. With S ephan's cui r t (NGC 7317, NGC 7318A, NGC 7318B, NGC 7319, and NGC 7320), however, five galaaieu are involved in a colossal tug-of-war that's tearing the systfmiapa t.lN all is dastruction, though. Is huge gas clouds collide, new star clusters comprising millions of stars form.

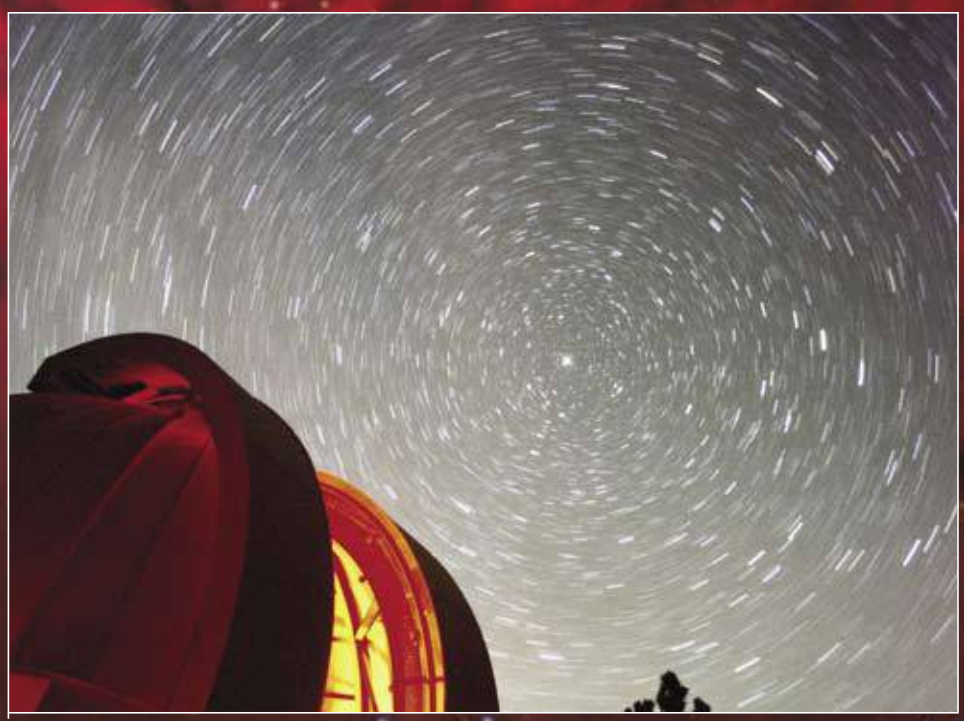
STEPHAN'S QUIN ET(14.5-inch RC Optical yste s la s ca Cas3egrain telescope at f/8, SBIG STL-11K CC camer , 210-minute expocure) /// TONY AND DAPHNE HALLAS, EORES bILL, ALIF RNIA

ELUSIVE MERCURY ia n t often o served bec use it n ser st a lower r g t of th Moo e (T ipod-mounted Sony DSC-F717 digital ar from the Sun. When you can use a brighter object to find it — camera, 1.2-second exposure, taken March 11, 2005, at 6:58 P.M. such as the Moon — it's easy to see. Here, M rcury ies 4° to CST) /// DON WHEELER, MONROE, LOUISIANA

HE EB LA D hWS Y UR EVE but it's the star cluster that has the designation NGC 7129. It's a young cluster, too — most of the stara are less than 1 million years old. (12.5-inch Parallax Instruments Ritchey-Chrétien reflector at f/9, SBIG ST-10XE CCD camera, L GB im ge ith exposures of 240, 90, 90, ane 10 m u s, respectively) / BOB AND JANI E FERA AUBU N, CAL?FORNI

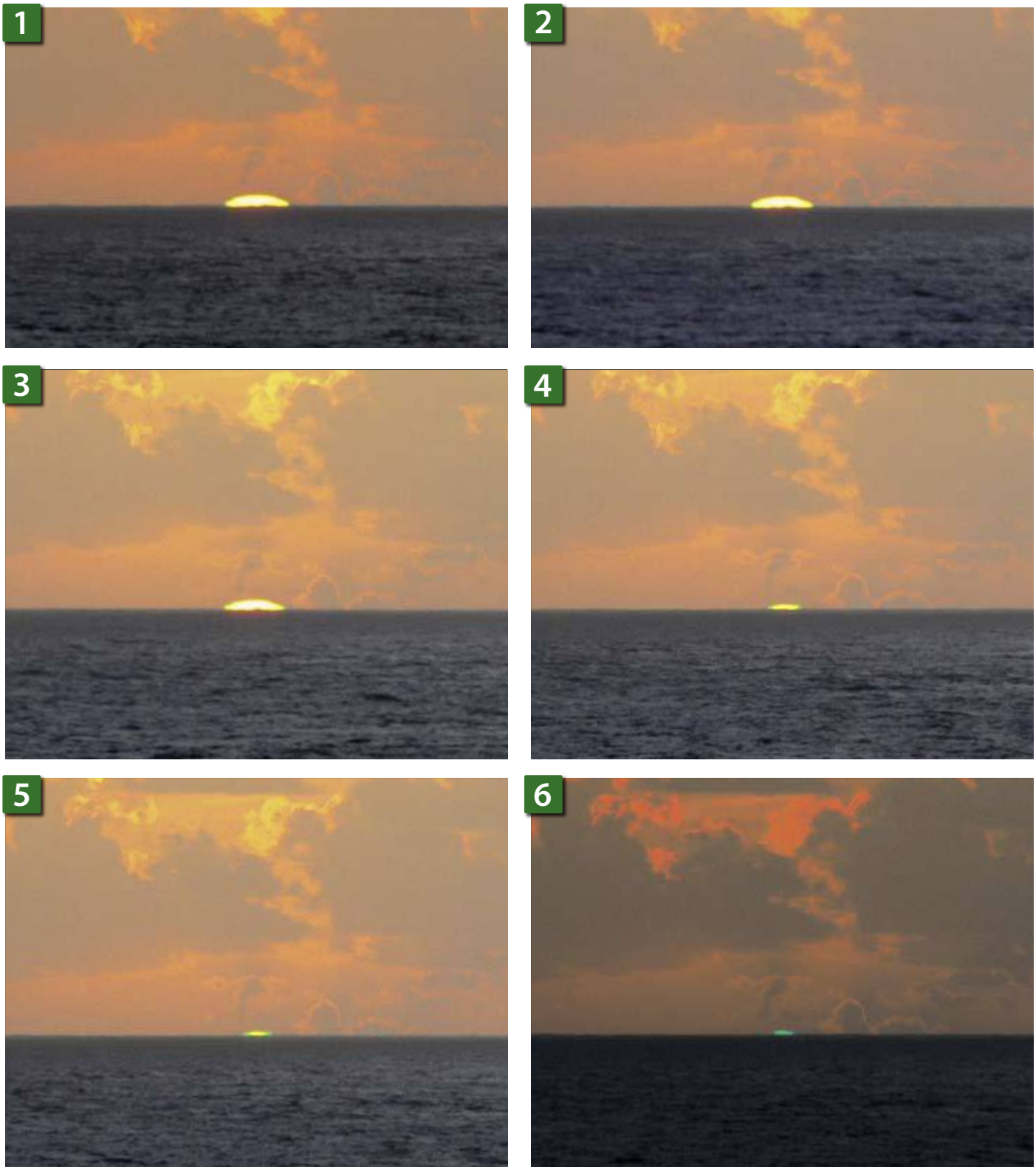
THE FOXFUR NEBULA lies within the same gaseous complex as the more familiar Cone Nebula (NGC 2264). The Foxfur Nebula is difficult to observe visually because the relatively bright star S Monocerotis lies near by. The complex is 2,700 light-years away. (14.5-inch RC Optical System classical Cassegrain telescope at f/8, SBIG STL-11K CCD camera, LRGB image with exposures of 150, 120, 120, and 120 minutes, respectively) /// TONY AND DEBRA HALLAS, FORESTHILL, CALIFORNIA

Send your photos to: ASTRONOMY reade hgalle v PtOo lx 1612, Waukesha, WI 53187; e-mail to readergallery@astronomy.com.
Please include your full name, date and location of image, and complete photo data: telescope, eam h f m, anr exposire inforr tion.c



ROUND AND ROUND goes Earth, spinning once each day. We don't feel its motion, but we can photograph proof it's moving. These star trails are centerud on Polaris (Alphax Ursae Minoris), which is the bright, untrailed star in the center. (Canon EOS Digital Rebel, 18mm lens setting at f/5, ISO 1600, 17-minute exposure) /// **DREW J. EVANS AT STAR HILL OBSERVATORY, SAPELLO, NEW MEXICO**

THE GREEN FLASH is an elusive phenomenon rarely seen at a sunset's last moment. Becwuse a distant horizon is required (to maximize the amount of air between you and the Sun), most Green Flash sightings are at sea. (Panasonic DMC-FZ20 video camera, tripod-mounted, 72mm lens at f/5.2, 1/80-second frames) /// **PAUL HIDER ABOARD THE M/S *PAUL GAUGUIN* NORTH OF PITCAIRN ISLAND**



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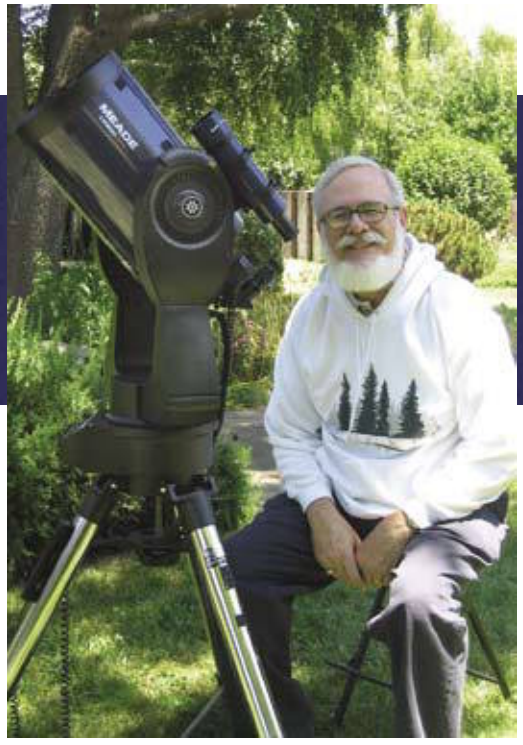

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M37 – Open Star Cluster

M16 – The Eagle Nebula

M53 – Globular Star Cluster

M97 – The Owl Nebula

M100 – Spiral Galaxy

All hoto's taken b Hilary Jones with his 8" LX200GPS using a Meade f/3.3 focal reducer in alt-az mo e

M37 – Open Star Cluster: 3x3 m sanc (9 sectors), 60 frames/sector x 10 seconds/frame.

16 –The Eagle Nebula: 2x2 mosaic, 1.2 hours (in center), 1 -15 cands/f$ame.

M53 – Globular Star Cluster: 693 frames x 10 seconds.

M97 – The Owl Nebula: 3.3 hours, 10-30 seconds/frame.

M100 – Spiral Galaxy: 2x2 mosaic, 810 frames x 10 seconds.

U.S. Patents Pending. 30-05115.